PROCEEDINGS

OF THE

AMERICAN SOCIETY

FOR

HORTICULTURAL SCIENCE

VOLUME 51

H. B. Tukey, Editor and Business Manager
Michigan State College,
East Lansing, Michigan

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CONSTITUTION*

ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

ARTICLE III

Voting members: Any person who has a baccalaureate degree and holds an official position in any agricultural college, experiment station, or federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

Associate Members: Any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

ARTICLE V

The officers shall consist of a President, a Vice-President, a Secretary-Treasurer, and sectional chairmen to represent the subject-matter sections of the Society.

ARTICLE VI

The Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

*As revised and adopted at the Boston meeting, December 29, 1946.

BY-LAWS

Section 1—*Duties of Officers:* The President shall preside at business meetings and general sessions of the society, deliver an address at the regular annual meeting, and serve *ex officio* as a member of the executive committee.

The Vice-President shall preside at business meetings and general sessions of the Society in the absence of the President and serve *ex officio* as a member of the executive committee.

The Sectional Chairmen shall preside at sectional meetings and serve *ex officio* as members of the executive committee.

The Secretary-Treasurer shall keep the records of the Society; mail to members a call for papers for the annual meeting at least 30 days prior to closing date for acceptance of papers, and at least 3 months prior to the annual meeting shall request of members suggestions regarding nominations, matters of policy and general welfare of the Society; serve *ex officio* as a member of the executive and program committees; collect dues from members; and conduct the financial affairs of the Society with the aid and advice of the chairman of the executive committee.

Section 2—*Executive Committee:* There shall be an executive committee consisting of the retiring President, who shall be chairman, the President, the Vice-President, the Sectional Chairmen, the chairmen of regional groups, the Secretary-Treasurer, the Editor-Business Manager, and two members elected at large for terms of two years each, retiring in alternate years. This committee shall act for the Society in the interim between annual meetings; shall fix the date for the annual meeting; shall present at each annual meeting nominees for members of the nominating committee; shall act on admission of all associate members, regional groups and junior branches and in special cases may elect to voting membership persons of high qualifications but otherwise ineligible; shall consider matters of general policy or welfare of the organization and present its recommendations at the annual meeting of the Society.

Section 3—*Nominating Committee:* There shall be a committee on nominations consisting of two members from each of the sectional groups who shall be nominated by the executive committee and elected by ballot at each annual meeting of the Society. It shall be the duty of this committee, at the following annual meeting to present a list of nominees for the various offices, committees (except the Nomination Committee), representatives, and sectional chairmen who shall be selected after consultation with the sections. This committee shall also nominate referees and alternates upon special subjects of investigation or instruction which may be referred to it for consideration by the Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned to them and to report the present status of the same.

Section 4—*Program Committee:* There shall be a committee on program consisting of five (5) members, including the Secretary and the Editor. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society. It shall receive titles and arrange the program of the annual meeting; arrange symposia; accept or reject titles, and may invite non-members to participate.

Section 5—*Editorial Committee:* There shall be an Editorial Committee consisting of five members. One member shall be elected each year to serve for five years. It shall be the duty of this committee to formulate the editorial and publication policies of the Society; to assist the Editor in reviewing and editing papers and shall have final authority to reject any paper deemed not worthy or unsuitable for publication in the PROCEEDINGS. The Committee at the call of the senior member shall elect a chairman from among its members, who shall serve for the calendar year.

The Committee shall appoint an Editor and Business Manager of the PROCEEDINGS, subject to the approval of the Executive Committee. He shall serve for a period of 3 calendar years, and shall be charged with editing, publishing and

distributing the PROCEEDINGS. He shall serve *ex officio* as a member of the Executive Committee.

Section 6—*Membership Committee:* There shall be a committee on membership whose duties shall be the promotion of membership in the Society.

Section 7—*Auditing Committee:* There shall be a committee to audit the books of the Society and report their condition at each annual meeting.

Section 8—*Committee on Local Arrangements:* There shall be a committee on local arrangements who in cooperation with the Secretary-Treasurer will have charge of all local arrangements for the annual meeting.

Section 9—*Quorum:* Ten members of the Society shall constitute a quorum for the transaction of business at a regularly called meeting of which at least 30 days notice shall have been given to members.

Section 10—*Annual Dues:* The annual dues of the Society shall be six dollars.

Section 11—*Amendment to the By-Laws:* The by-laws may be amended at any regular meeting by a two-thirds vote of members present providing a copy of such amendment has been sent to all members at least 30 days prior to the meeting.

Section 12—*Regional Groups:* Upon the presentation of a petition signed by ten or more members of this Society residing within a stated region, the executive committee may approve the formation of a regional group affiliated with this Society. Such group must elect as a minimum number of officers as chairman, a vice-chairman and a secretary and shall present an annual report to the Secretary-Treasurer of the national Society to include the names of its officials and a review of its meetings or other activities. Publication of this report in full or in part shall be made in the PROCEEDINGS of this Society. Papers presented at regional group meetings may be published on the same basis as papers presented at the regular annual meeting.

Section 13—*Junior Branches:* A student horticultural group at a college or university, operating under the supervision of a member or members of this Society, may organize as a Junior Branch of the American Society for Horticultural Science upon approval of the executive committee and the payment of an annual fee of six dollars for the branch. Each branch shall receive a copy of all publications of the Society. Such a branch shall elect a chairman, a vice-chairman and a secretary-treasurer and shall present an annual report of its activities to the national Secretary-Treasurer. Such groups may hold meetings in conjunction with the annual meetings of this Society and a report of such meetings, not including individual papers, may be included in the PROCEEDINGS.

Section 14—*Term of service for elected officers:* The term of service for elected officers shall be from the close of the annual meeting at which they are elected until the close of the next annual meeting.

SOCIETY AFFAIRS

RESUMÉ OF THE ANNUAL MEETING OF THE AMERICAN SOCIETY FOR HORTICULTURAL SCIENCE, CHICAGO, ILLINOIS, DECEMBER 29, 30, and 31, 1947

The American Society for Horticultural Science held its annual meeting in a three-day session at the Palmer House in Chicago, Illinois, in fourteen sectional meetings, one symposium, one joint session and two evening meetings.

The subject matter content of the meeting is indicated by the titles to the sessions, as follows: Pomology — nutrition, breeding and propagation; growth regulators and chemical flower thinners; small fruits and grapes; fruit physiology and storage, and one general session. Vegetable Crops — tomatoes, herbicides and growth regulators; breeding and nutrition, potatoes, and one general session. Floriculture and Ornamental Horticulture — herbicides; growth regulators and nutrition; and two general sessions. A symposium on the subject "Dormancy" was held with the American Society of Plant Physiologists and the Physiological Section of the Botanical Society of America. A joint session on "The Breeding and Improvement of Horticultural Crops" was held with Section "O" of the American Association for the Advancement of Science. Round table discussions involved breeding methods for horticultural crops, mineral and nitrogen deficiency diagnosis, education and extension.

At the annual banquet, at which over 230 were present, Dr. Harold B. Tukey, the retiring president, presented an address on the subject, "Horticulture in Science and Society". Dr. M. J. Dorsey, Chairman of the Local Committee on Arrangements from the University of Illinois, was toastmaster.

REPORT OF THE EXECUTIVE COMMITTEE

AS ADOPTED BY THE SOCIETY

The Executive Committee met December 28, 1947, with the following members in attendance: G. F. Potter, Chairman; H. B. Tukey, J. E. Knott, F. S. Howlett, W. F. Pickett, L. E. Scott, L. C. Chadwick, Otis Woodard, John Walker, H. A. Rollins (for J. H. Waring), W. D. Kimbrough and L. D. Davis.

The report of the Secretary-Treasurer was presented. Reports were also received from the Editorial Committee and the Editor-Business Manager, H. B. Tukey.

The following action was taken by the committee:

1. The committee voted to hold the next annual meeting in Cincinnati, Ohio, September 8 to 10, 1948.
2. The committee recommended that an invitation be extended to the National Joint Committee on Fertilizer Application to meet with the Society on September 8.
3. The committee unanimously recommended that the Society become a charter member of the proposed American Institute of Biological Sciences.
4. The committee recommended that the dues of the Society be increased to $6.00 per year.
5. The committee recommended that the Society establish a life membership at $100.00.
6. It was recommended that the Society establish a committee on Rehabilitation of Foreign Libraries, consisting of three members, to be appointed by the President.
7. The Committee recommended that a section on "Processing" be established.
8. It was recommended that the Society instruct the Secretary to send printed bills for membership dues for the calendar year, said bills to be sent out in January and to be payable on or before March 1. On, or about March 1, a second bill is to be sent, reminding those who have not paid, that names of delinquent members cannot be included in the Membership Roll in the PROCEEDINGS.
9. The committee recommended that the Secretary be instructed to explore the possibility of a joint meeting of 1949, with the Soil Science Society of America, the American Society of Agronomy, and, if possible with the American Society of Plant Physiologists, and the Botanical Society of America.

10. The secretary was instructed to invite the National Association of Extension Specialists in Horticulture to affiliate with the Society, and if possible, meet at the same time and place.

11. The committee instructed the secretary to contact a Certified Public Accountant regarding an audit, and check on Society business transacted by the publisher.

The matter of a journal was discussed at some length and Dr. Potter reported that the Executive Committee had received suggestions from a number of individuals that the quality of the papers presented at the sessions and published in the PROCEEDINGS should be improved. It was pointed out that the program committee has authority to reject papers believed not to be up to Society standards. The committee recommended that two outlines be prepared by the Editor of the PROCEEDINGS as follows: (1) Suggestions to Authors on Preparation of Paper, and (2) Guide to Reviewers.

BUSINESS MEETING

At the Business Meeting of the Society, held December 31, 1947, the report of the Secretary-Treasurer was received and accepted. Likewise the recommendations of the Executive Committee as presented, were adopted. The Society voted overwhelmingly to become a charter member of the American Institute of Biological Sciences and to increase the dues to $6.00 per year.

The reports of Standing and Special Committees were received and accepted and are given below.

The Membership Committee recommended greater attention to securing County Agents, Graduate, and Under-Graduate Students, as members of the Society.

V. R. Boswell, as representative of the Society on the A.A.A.S. Council, reported that the A.A.A.S. was planning a Centenary meeting in Washington in September, 1948 and would not be able to make arrangements for the 1948 meeting of the Society.

Upon recommendation of L. H. MacDaniels, a new Committee on "Varieties" was approved, the members to be appointed by the President.

Upon motion of Damon Boynton, a new Special Committee on "Mineral Deficiency and Diagnosis", consisting of three members, to be appointed by the President was approved. The purpose of the committee is to compile material on diagnostic procedures and method of presentation of data.

The Nominating Committee made its report, which was accepted, nominating for office those whose names appear in the list of officers on page vii of these PROCEEDINGS. Special attention was given to increasing the membership, by appointment of one member in charge of the Active Membership Campaign, another in charge of Associate Membership, and a third in charge of Junior Branch Membership. Each of these individuals was requested to appoint as many assistants as he desired.

Voting, and Associate Membership, was discussed and the concensus of opinion was informally obtained that the secretary should distinguish between the two types, only for the purpose of determining the obligation of the Society to the American Institute of Biological Sciences.

The Executive Committee appointed the Nominating Committee for 1948, as follows: O. A. Lorenz, *Chairman*, R. D. Sweet, Ray Keen, W. H. Alderman, F. F. Cowart, L. O. Van Blaricom, and W. V. Cruess.

REPORT OF THE SECRETARY

The Secretary reported that membership of December 31, 1947 was 1095, an increase of 95 during the year. The number of foreign members is increasing.

During the year, three news letters were dispatched to the membership, presenting matters of interest to the Society.

The Secretary met with the secretaries of several other plant science societies at Cincinnati, Ohio, May 26, to discuss matters of mutual interest to these organizations.

The four sections of the Society held enthusiastic meetings during the year, reports of which are presented in this Volume of the PROCEEDINGS.

The following members passed away during the year: C. E. Abbott, G. M. Bahrt, Frank Beach, M. A. Blake, F. R. Durham, H. P. Gould, E. H. Hoppert, G. L. Philp, H. H. Plagge, H. W. Richey, and E. B. Tussing.

REPORT OF THE TREASURER
FOR PERIOD ENDING DECEMBER 31, 1947

Balances

Wayne County National Bank — February 1, 1947		-0-	
Lincoln Rochester Trust Company — January 1, 1947		$13,543.10	
East Lansing State Bank — February 1, 1947		395.25	
Total			$13,938.35

Receipts

Membership dues collected (net after collection charges)	$5,492.10		
Less — Money order returned to Tukey for indorsement	5.00	$5,487.10	
Unknown Source (East Lansing State Bank)		15.00	
Deposits made by W. F. Humphrey Press Inc.		8,932.05	
Re-deposit of returned (W. F. Humphrey Press Inc.)		20.68	
Total Receipts			14,454.83
Total Funds on Hand			$28,393.18

Disbursements

Printing and Engraving	$12,387.27	
Office Supplies and Expense	237.43	
Salaries	711.79	
Bond	30.00	
Royal Typewriter purchase	155.58	
Bank Charges	4.84	
Miscellaneous Expenses	77.75	
Returned checks charged to bank account	56.91	
Convention expense (Howlett)	70.08	
Convention expense (tips paid to Leonard Gamble)	93.20	
Leonard H. Vaughan Memorial Award	1,000.00	
Legal Expense	47.50	
Total Disbursements		$14,872.35
Cash Balances — December 31, 1947 —		
Lincoln Rochester Trust Company	$10,611.75	
Wayne County National Bank	2,909.08	
Totals		$13,520.83
		$28,393.18

I hereby, certify that to the best of my knowledge all funds of the society have been properly accounted for and the records of the association are in balance with the opening and closing cash balances.

Respectfully submitted,
HAROLD R. GERBERICH, CPA. (Ohio)

LEONARD H. VAUGHAN MEMORIAL RESEARCH AWARDS

The Leonard H. Vaughan Memorial Research Awards in Horticulture for papers appearing in Volumes 47 and 48 of the PROCEEDINGS are as follows:

In *Floriculture,* to D. C. Kiplinger and Glen Fuller of the Ohio State University, and Battelle Memorial Institute, respectively, at Columbus, Ohio, for their paper entitled, "Selenium Studies with Some Flowering Greenhouse Plants". Proc. Amer. Soc. Hort. Sci. 47: 451–462.

In *Vegetable Crops,* to William H. Lachman, University of Massachusetts, Amherst, Mass. for his paper entitled, "The Use of Oil Sprays on Selective Herbicides for Carrots and Parsnips II". Proc. Amer. Soc. Hort. Sci. 47: 423–433.

REPORT OF THE COMMITTEE ON EDUCATION

The session on Education for the evening of the 29th, was devoted for the most part to an informal roundtable discussion of the contents of the beginning course in Horticulture. In some institutions, the first course is required and in others, it is elected only. Out of this discussion there emerged the idea that it might be well, during the next year, for a committee to give consideration to what might be included in a general course in Horticulture, covering fruits, flowers and vegetables. After considerable discussion of the general problem of instruction in Horticulture a study group was set up along the following lines.

First, the general or beginning course; second, teaching methods; and third, graduate work. The personnel of these study groups, which was reported to the business meeting of the Society, is as follows:

Group I. Post of Cornell, Russell of Michigan, Hibbard of Missouri, Bouquet of Oregon, Birkeland of Illinois, Falkenberg of Purdue, Alderman of Minnesota, Shoemaker of Guelph, Ontario, with Edgecombe of Utah, leader.

Group II. The membership of the study group on teaching methods is as follows: Pickett of Kansas, Lott of Illinois, Volz of Iowa, Chadwick of Ohio, Edmond of Louisiana, Wolfe of Florida, with Smock of Cornell, leader.

Group III. To act as a spearhead to discuss graduate work, the Committee is as follows: Haber of Iowa, Yeager of New Hampshire, MacDaniels of Cornell, Knott of California, Miller of Louisiana, with Howlett of Ohio as leader.

The Society's Committee on Education for 1948 recommended for appointment is as follows: Smock of Cornell, Howlett of Ohio, Adriance of Texas, Ragland of Mississippi, Shoemaker of Guelph, Ontario, Alderman of Minnesota, Hanna of California, with Haut of Maryland, Chairman.

It is understood that each group will feel free to arrange for any presentation next year that seems most suitable.

M. J. Dorsey, *Chairman*

REPORT OF COMMITTEE ON MARKET QUALITY

The resolution passed by the Society, relative to encouragement of research in the physiological aspects of marketing and the need for a bibliography relative to the problems involved, was sent to the Directors of the State Experiment Stations. The suggestions were favorably received as evidenced by the comments made. The problem of a bibliography, supported by Hope-Flanagan funds, is being proposed by the Regional Administrative Advisors for submission to the Agricultural Research Administration. It has a fair chance to be accepted and undertaken for the following commodities: citrus, apples, peaches, and tomatoes.

Dr. C. O. Bratley, Fruit and Vegetable Assistant to the Administrator of the Marketing Act, and a member of the committee, feels that the Society through a committee should continue to maintain an active interest in the horticultural aspects of marketing. A list of both formal and informal current projects in horticulture that relate to the maintenance of market quality is being collected and will soon be ready for dissemination.

The committee proposed, and the Society adopted, the following:

1. A session at the next annual meeting consisting of papers relating to the physiological aspects of marketing, followed by an evening round-table discussion of the problem.

2. That a letter be directed to the proper authorities in charge of the administration of the Marketing Act urging the development of a technical bibliography on the various aspects of maintaining market quality.

3. The annual listing of new projects that relate to market quality.

4. The continuance of a committee to promote interest in this field.

R. L. Carolus, *Chairman*	F. S. Jamison
H. C. Thompson	F. C. Gaylord
L. E. Scott	L. L. Claypool
Alex Laurie	O. C. Roberts
C. O. Bratley	L. L. Morris

REPORT OF THE EDITORIAL COMMITTEE

The Editorial Committee met Sunday afternoon, December 28, 1947 with H. M. Munger, S. H. Yarnell, F. S. Howlett in attendance. Dr. H. B. Tukey, Editor, met with the Committee to discuss matters of editorial policy and procedure. Suggestions were made for continuous improvement of the PROCEEDINGS. It was agreed that each of the manuscripts submitted for publication would be sent to a competent reviewer or reviewers as well as to one member of the Editorial Committee. It was also agreed that at this time no move should be made to establish a Journal. Dr. Tukey reported that the plan would be to publish yearly two volumes of the PROCEEDINGS, the first sometime in June and the second at the end of the year.

REPORT OF COMMITTEE ON JUNIOR BRANCH MEMBERSHIPS

The committee on Junior Branch memberships met and voted to publish a small two-page leaflet. The name of the Society and its purpose would appear on the front page. On the inside of the front page the objectives of Junior Branch memberships are to be stated. The advantages of such a society and the procedure of organizing such a branch are to be discussed on the inside of the back page. On the last page will appear a copy of Section 13 of the By-Laws of the American Society of Horticultural Science. Section 13 reads as follows:

"A student horticultural group at a college or university, operating under the supervision of a member or members of this Society, may organize as a Junior Branch of the American Society for Horticultural Science upon approval of the executive committee and the payment of an annual fee of six dollars for the branch. Each branch shall elect a chairman, a vice-chairman and a secretary-treasurer and shall present an annual report of its activities to the national secretary-treasurer. Each branch shall receive a copy of all publications of the Society. Such groups may hold meetings in conjunction with the annual meetings of this Society and a report of such meetings, not including individual papers, may be included in the PROCEEDINGS."

The following amendment to this section is proposed for the consideration of the Society: "Undergraduate students may become associate members at a cost not to exceed the actual cost of the PROCEEDINGS."

E. C. STAIR, *Chairman*
W. P. JUDKINS
GEORGE KESSLER

REPORTS OF THE SECTIONAL MEETINGS

NEW ENGLAND SECTION

Summer Meeting—August 21, 1947:—The summer meeting of the section was held at the University of Massachusetts, Amherst, with 21 members in attendance. Routine matters were considered. Discussion arose as to the desirability of changing the form of the annual meeting of the Society as well as the form of publication. The members also discussed the proposed American Institute of Biological Sciences.

Winter Meeting—January 31, 1947:—The winter meeting of the New England Section was held in the Biology Laboratory, Harvard University, Cambridge, Massachusetts, with 50 members in attendance. Routine matters of the section including a report of the national meeting were presented. It was moved and carried that the New England Section urge the National Society to publish an index to the first 50 volumes. The officers elected for 1948 were: *Chairman,* H. A. Rollins; *Vice Chairman,* C. H. Blasberg; and *Secretary,* A. C. Bobb.

GREAT PLAINS SECTION

The Great Plains Section met at Morden, Manitoba, August 25 to 27, 1947 with the Dominion Experimental Station as host. This was the first meeting of the Section since 1945 and the attendance greatly exceeded expectations. The officers elected for 1947–48 were as follows: *Chairman,* John Walker; *Vice Chairman,* S. A. McCrory; *Secretary,* A. C. Hildreth.

SOUTHERN SECTION

The tenth annual meeting of the Southern Section was held in conjunction with the forty-fifth annual convention of the Association of Southern Agricultural Workers in Washington, D. C. on February 12 to 14, 1948. The program consisted of two symposia, two roundtable discussions, one joint session, one session for Extension workers, and one session for general papers. The symposia were: "Recent Research on the Pecan and Tung" with Dr. George F. Potter, as Chairman; "Recent Studies of Vegetable Crop Breeding" with Dr. J. M. Jenkins as Chairman; and "Packaging of Fruit and Vegetables" with Mr. John Bagby as Chairman. The roundtable discussions were: The Training of Non-Majors, Majors, and Graduates in Horticulture with Dr. J. B. Edmond as Chairman; and the Southern Vegetable Crop Variety Trials with Dr. B. L. Wads as Chairman. The joint session was with the Agricultural Economics and Rural Sociology Section on Production and Marketing of Sweet Potatoes with Dr. J. C. Miller as Chairman. The session for Extension workers, with Dr. F. S. Andrews as Chairman, included a demonstration on the construction of hotbeds by the winning team of the National Junior Vegetable Growers Association and a tour of the Plant Industry Station. All sessions were well attended and a total of 36 papers were presented.

The banquet and social evening was held at the Willard Hotel with Dr. B. L. Wade as toastmaster. Distinguished guests were: Dr. T. H. McHatton, Dr. J. C. Miller, Dr. Laurenz Greene, and Dr. G. F. Potter, past presidents, and Dr. F. S. Howlett, Secretary-Treasurer of the Society. The Section authorized the enlargement of the Executive Committee and the creation of three new committees — one on program, a second on teaching and extension methods, and a third on membership. Dr. S. H. Yarnell was elected to serve as general chairman of Southern Vegetable Variety Trials and the office of Secretary was changed to that of Secretary-Treasurer.

The following officers were elected for 1948–49: *Chairman*, J. B. Edmond; *Vice Chairman*, J. H. Weinberger; and *Secretary-Treasurer*, J. L. Bowers.

Some Interrelationships Between Calcium, Magnesium and Potassium in One-Year-Old McIntosh Apple Trees Grown in Sand Culture[1]

By JOHN C. CAIN, *New York State Agricultural Experiment Station, Geneva, N. Y.*

PREVIOUS investigations in the nutrition of fruit trees in New York (2, 3, 4, 5, 6, 8) have indicated a rather general reciprocal relationship between the potassium and magnesium content of the foliage of apple trees. A number of cases have been reported in the literature where magnesium deficiency symptoms of fruit trees have been increased in severity by the use of potash fertilizers (3, 6, 13, 18) and nearly all investigators who have analyzed the foliage show that this symptom is associated with low magnesuim content and high potassium content in the tissue. The increase in the potassium content of leaves showing magnesium deficiency symptoms, seems to take place whether or not potash fertilizers have been used, but may be exaggerated by the use of the fertilizer. Chapman and Brown (9) reported that potassium deficient citrus plants accumulate excessive quantities of calcium, magnesium and sodium.

There seems to be a rather general interrelationship between the major nutrient cations in plants but so far a satisfactory mathematical expression for predicting this behavior has not been found, although a number of approaches have been made along this line (7, 11, 12, 14, 19).

The effect of one ion on the activity, function or movement of another ion within the plant has been variously referred to as antagonism, nutrient balance, cation ratio and other similar expressions, depending on the views of the investigator and the nature of the research. Osterhout (15) was among the first to use the term "antagonism" in relation to plant nutrition, defining this term as the act of one substance preventing the toxic effect of another. He also clearly distinguished between the terms "nutrient" and "balance" with respect to antagonism and toxicity in plant culture solutions; a balanced solution, one that is not toxic to the plant because of mutual antagonism, or balance, may be of little or no nutrient value to the plant. On the other hand a solution of high nutrient value may be unbalanced and produce toxic effects in the plant.

The investigations on which the present paper is based were undertaken in order to gain more information on the interrelationships between Ca, Mg and K in the foliage of apple trees and to determine the extent to which the leaf content of these nutrients and the occurrence of deficiency symptoms is affected by one or more other cations (8).

EXPERIMENTAL PROCEDURE

One-year-old McIntosh apple trees were selected from the nursery on the basis of uniformity of tops and root systems. The tops were cut

[1]Journal Paper No. 737, New York State Agricultural Experiment Station, Geneva, N. Y.

back to two buds above the bud union, the roots were pruned rather severely and washed thoroughly. The plants were then set in 1-gallon glazed crocks in coarse quartz sand. Each crock was provided with a drain hole covered with a layer of glass wool.

The crocks containing the trees were placed in the greenhouse and flushed with distilled water three times weekly. After 3 weeks the tops were from 6 to 8 inches in height, only one shoot being allowed to grow on each tree. The plants were then arranged into four replicate blocks of 32 treatments according to the height of the shoots so that each treatment had approximately the same range of plant sizes. Less vigorous and poorly growing plants were eliminated.

For a study of this type it was thought desirable to maintain a constant level of supply[2] of all nutrients except the one varied for each series. Thus, even though it was necessary to vary the total ionic concentration, a system of mixing the nutrient components was devised for this purpose. Table I shows the ionic concentrations used for each treatment and the nature of the nutrient solutions used. By this system it was necessary to shift the proportion of ammonium and nitrate ions in making up the nitrogen supply and to add chloride ion to the solutions of higher cation concentrations. However, this was thought to be a better procedure than to vary the amount of more than one of the cations under investigation at a time.

The nutrient solutions were prepared from stock solutions at the time of application and each crock received 250 ml of its respective mixture three times weekly. This was found to be sufficient to make the crocks drain. All crocks were flushed with distilled water once each week to prevent salt accumulation in the sand.

At the end of 16 weeks of treatment the plants were harvested, leaf symptoms recorded and the leaves and stems dried and analyzed separately for each plant. The methods of analysis used were a modification of those of Peech (16).

RESULTS

The data for each treatment are presented in Table IIa and those showing the combined means for all treatments receiving a single cation level are show in Table IIb.

The dry weight and height figures indicate increases due to all three cations. In comparing these two values (Table IIb) it is seen that increasing supplies of either calcium or magnesium produced greater increases in dry weight than in height of plant. This indicates that the primary response to these cations is that of secondary thickening. The growth response to potassium is slightly greater in height than in dry weight, indicating a primary response in stem elongation.

Tissue Composition:—The Ca, Mg and K content of the leaves are shown graphically in Fig. 1. The cation content here is expressed as milliequivalents per 100 grams of dry weight in order to compare the changes in concentration on a chemically equivalent basis.

Each cation increased in concentration in the leaves as its respective

[2]Concentration of nutrients in solution supplied to plant.

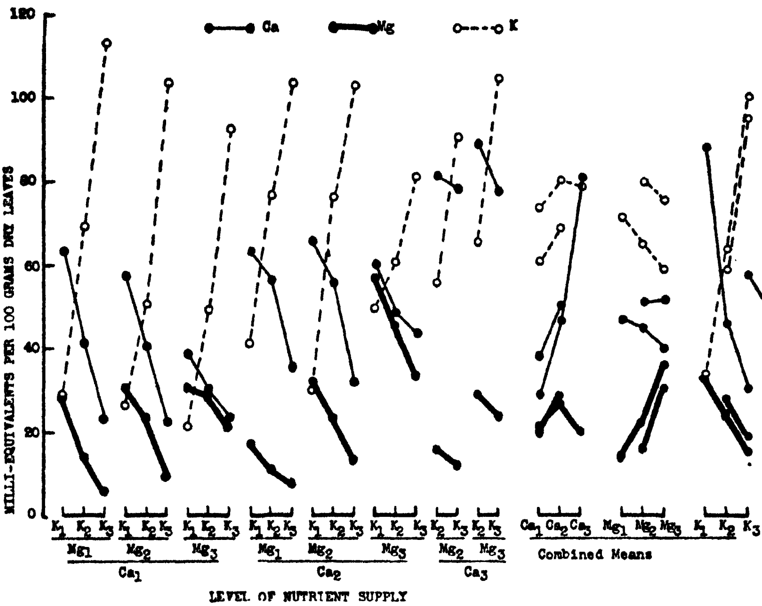

FIG. 1. The effect of varying the level of supply of Ca, Mg, and K in the nutrient solution on their content in the foliage of 1-year-old McIntosh apple trees grown 16 weeks in sand culture.

supply was increased in the nutrient solution. The increase, however, is not linear with respect to the concentration of nutrient supply, but approximately linear with its logarithm, since the level of supply values in this graph (subscript numerals) are approximately proportional to the logarithm of the concentrations used in the nutrient solution (Table I).

It can be seen from the curves that both Ca and Mg decrease sharply with increasing K, but not in exact chemically equivalent amounts. The increase in K is usually greater than the combined decrease in Ca and Mg. At the highest levels of Ca and Mg this effect is less marked. Conversely the K content of the leaves was decreased by increasing the Mg supply but less noticeably with increasing Ca.

Increasing the Ca supply decreased the Mg and K content of the foliage only at the Ca_3 level of supply, these values increasing slightly between Ca_1 and Ca_2. Both Ca and K decreased in the leaves with increasing Mg. These relations are more easily seen from the data for combined means.

Fig. 2 shows the effect of varying the supply of each cation on the content of the other two in both leaves and stems. Here the data from the sets of plants with intermediate levels of supply were used, thus increasing both the range of cation concentrations and the number of increments of supply. It is seen here that each cation increases in both leaves and stems as its supply is increased, the increase being more pronounced in the leaves than in the stems for Mg and K.

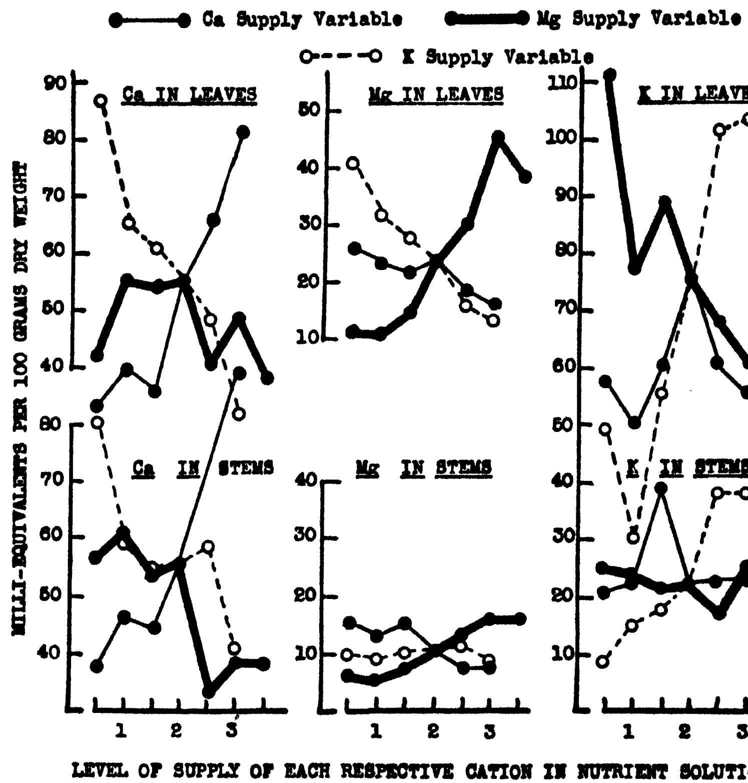

FIG. 2. The effect of increasing the concentration of Ca, Mg and K individually in the nutrient solution on their content in the foliage of 1-year-old McIntosh apple trees grown 16 weeks in sand culture.

The Ca content of both leaves and stems is greatly decreased by increasing the K supply, falling from 88 m e/100 grams to 30 m e/100 grams in the leaves, and from 80 m e/100 grams to 40 m e/100 grams in the stems when the K supply is increased from 0.3 m e/L to 25.0 m e/L in the nutrient solution. The calcium content of the tissue was decreased to a lesser extent by magnesium, being more noticeable in the stems than in the leaves.

The Mg content of the leaves is decreased markedly as the K supply is increased but is relatively unchanged in the stems. Calcium caused a slight decrease in the Mg content of both leaves and stems.

The K content of the leaves was greatly reduced by increasing the Mg supply but that of the stems was relatively unchanged. Thus, there seems to be a rather strong reciprocal relationship between K and Mg in the leaves, but this is not so apparent in the stems of the plants.

Potassium has a rather strong effect on the Ca content but the reverse is less noticeable. Calcium has less effect on the Mg content than Mg has on the Ca content.

TABLE I—THE IONIC CONCENTRATION OF NUTRIENT ELEMENTS FOR THE VARIOUS TREATMENTS (MILLI-EQUIVALENTS PER LITER)

Treatment No.	Components			Ca	Mg	K	N	P*	S
	Ca	Mg	K						
1	1	1	1	1.00	0.30	0.40	22	2	4
2	1	1	2	1.00	0.30	4.00	22	2	4
3	1	1	3	1.00	0.30	25.00	22	2	4
4	1	2	1	1.00	3.00	0.40	22	2	4
5	1	2	2	1.00	3.00	4.00	22	2	4
6	1	2	3	1.00	3.00	25.00	22	2	4
7	1	3	1	1.00	18.75	0.40	22	2	4
8	1	3	2	1.00	18.75	4.00	22	2	4
9	1	3	3	1.00	18.75	25.00	22	2	4
10	2	1	1	10.00	0.30	0.40	22	2	4
11	2	1	2	10.00	0.30	4.00	22	2	4
12	2	1	3	10.00	0.30	25.00	22	2	4
13	2	2	½	10.00	3.00	0.14	22	2	4
14	2	2	1	10.00	3.00	0.40	22	2	4
15	2	2	1½	10.00	3.00	1.40	22	2	4
16	2	2	2	10.00	3.00	4.00	22	2	4
17	2	2	2½	10.00	3.00	10.00	22	2	4
18	2	2	3	10.00	3.00	25.00	22	2	4
19	2	3	1	10.00	18.75	0.40	22	2	4
20	2	3	2	10.00	18.75	4.00	22	2	4
21	2	3	3	10.00	18.75	25.00	22	2	4
22	2	½	2	10.00	0.10	4.00	22	2	4
23	2	1½	2	10.00	1.00	4.00	22	2	4
24	2	2½	2	10.00	10.00	4.00	22	2	4
25	2	3½	2	10.00	50.00	4.00	22	2	4
26	½	2	2	0.32	3.00	4.00	22	2	4
27	1½	2	2	3.20	3.00	4.00	22	2	4
28	2½	2	2	25.00	3.00	4.00	22	2	4
29	3	2	2	60.00	3.00	4.00	22	2	4
30	3	2	3	60.00	3.00	25.00	22	2	4
31	3	3	2	60.00	18.75	4.00	22	2	4
32	3	3	3	60.00	18.75	25.00	22	2	4

*Phosphorus expressed as milli-moles.
Note: P and S were used as the ammonium salts. The nitrates of Ca, Mg and K were used up to a total of 17 me/liter, ammonium nitrate being used to make up the difference in nitrogen. When the total bases (Ca+Mg+K) exceeded 17 me/liter the chlorides were used to make up the excess cation required. A standard minor element mixture containing Mn, Zn, Cu, B and Mo was used in all solutions. Fe was added separately as the solutions were mixed and applied.

If these cations are placed in the order of their effect on reducing the tissue content of the other cations, the result is K>Mg>Ca. This is the same order as their mobilities, or relative rates of movement within the plant.

Thus, disregarding the essentiality of certain minimum quantities of each of these cations for growth, the quantity of each of these mineral nutrients in the leaf tissue seems to be a function of both supply and mobility. The ratio of these minerals present in the leaf tissue would then depend on the relative value of this function for each cation. That is, postulating an initial cation requirement, or deficit, in the leaf tissue, the cation to satisfy this deficit in greatest quantity is likely to be the one whose product of supply concentration and mobility is greatest. Suitable numerical values for the latter value in the plant are not established.

Fig. 3 shows the Mg content of the leaves plotted against the K

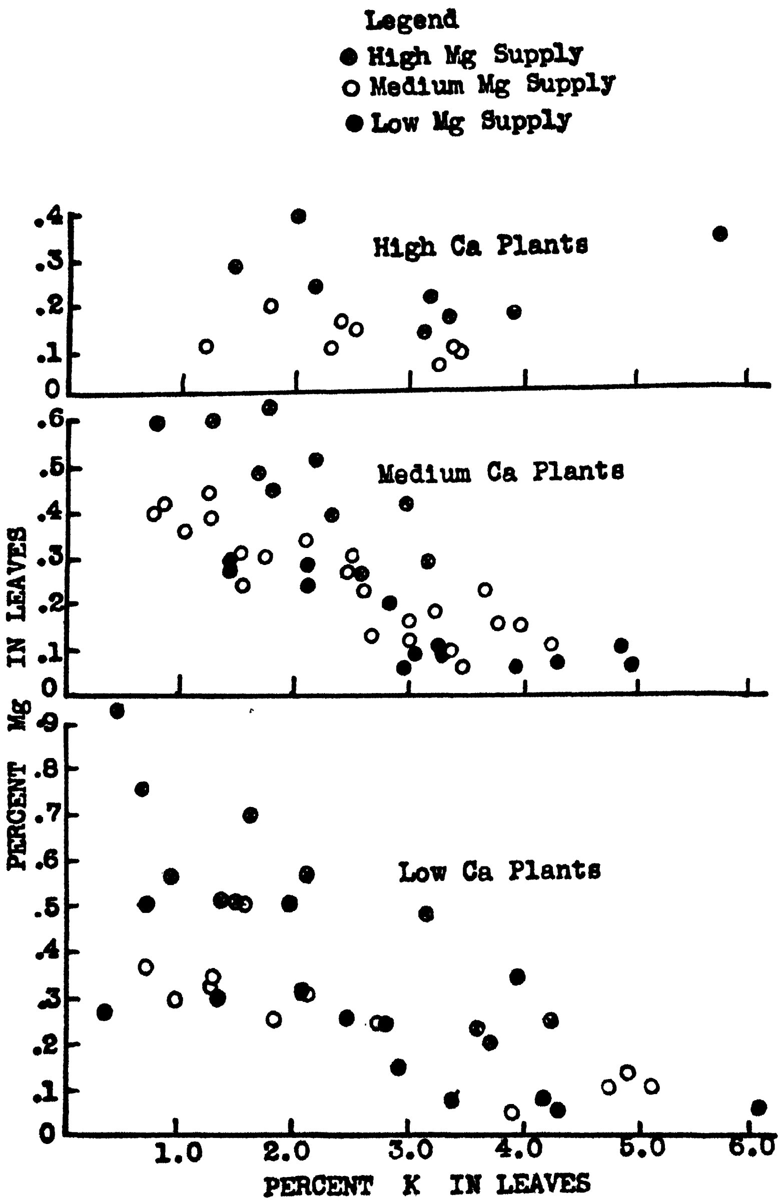

FIG. 3. The relation between K and Mg in the foliage of 1-year-old McIntosh apple trees grown 16 weeks in sand culture under differential nutrient supply.

content for all treatments. This scatter diagram indicates that the inverse relationship between the K and Mg content of the leaves is diminished somewhat by increasing the Ca supply but is not seriously affected by either of the other two cations except when the minimum percentage is approached. The minimum percentage of Mg possible before necrosis and defoliation occurs is between .08 and .15 per cent of dry weight in these plants. The minimum for K is between .7 and 1.0 per cent. In general, neither of these cations decreases below these respective levels in the leaf regardless of the concentration of the other.

Deficiency Symptoms:—The potassium and magnesium deficiency symptoms herein referred to are very much the same as those described by other investigators (1, 2, 4, 13, 17, 18, 20). Fig. 4 shows typical examples of these symptoms developed on these shoots.

The type of deficiency and relative degree of severity of those treatments showing symptoms are shown in Table IIa. It will be noted that these deficiency symptoms occurred only on treatments having

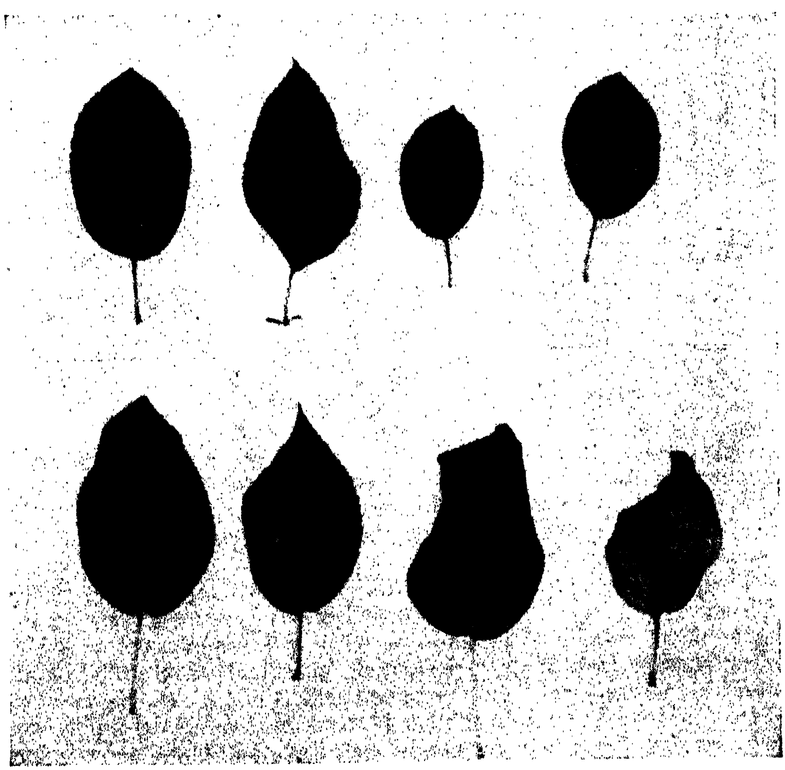

Fig. 4. Typical leaf symptoms produced on 1-year-old McIntosh apple trees grown 16 weeks in sand culture. Upper: K-deficiency symptoms produced by high Mg. Lower: Mg-deficiency symptoms produced by high K. Symptoms increase in severity from left to right.

TABLE IIa—THE EFFECT OF CA, MG AND K ON THEIR CONTENT IN MCINTOSH APPLE SHOOTS GROWN IN SAND CULTURE (EXPRESSED AS PER CENT OF DRY WEIGHTS)*

Treatment *Ca Mg K*	Stems					Leaves				
	Height (Mm)	Dry Weight (Gms)	Ca	Mg	K	Deficiency Symptom**	Dry Weight (Gms)	Ca	Mg	K
1 -1 -1	155	0.53	1.36	0.11	0.75		1.12	1.27	0.34	1.10
1 -1 -2	221	0.74	1.05	0.11	0.96	Mg-2	1.55	0.84	0.18	2.71
1 -1 -3	346	1.30	0.71	0.09	1.55	Mg-3	2.98	0.48	0.08	4.45
1 -2 -1	174	0.56	1.11	0.16	0.56		1.20	1.15	0.37	1.06
1 -2 -2	193	0.52	1.05	0.16	0.90		1.26	0.81	0.29	1.97
1 -2 -3	367	1.24	0.60	0.13	1.50	Mg-3	3.57	0.46	0.12	4.10
1 -3 -1	337	1.71	0.39	0.26	0.83	K-1	2.80	0.78	0.38	0.87
1 -3 -2	362	1.79	0.39	0.31	0.88		3.34	0.62	0.37	1.92
1 -3 -3	404	2.00	0.38	0.22	1.37		3.89	0.48	0.27	3.63
2 -1 -1	290	1.29	1.34	0.08	0.71		2.99	1.27	0.22	1.64
2 -1 -2	413	2.55	1.24	0.08	0.79	Mg-2	4.12	1.14	0.14	3.02
2 -1 -3	331	1.82	1.14	0.09	1.17	Mg-3	4.21	0.72	0.10	4.05
2 -2 -½	199	0.64	1.62	0.12	0.36		1.25	1.75	0.50	1.95
2 -2 -1	275	1.48	1.19	0.11	0.61		2.44	1.32	0.40	1.19
2 -2 -1½	367	2.29	1.11	0.12	0.70		3.44	1.24	0.34	2.21
2 -2 -2	382	1.80	1.13	0.13	0.89		3.00	1.12	0.30	3.00
2 -2 -2½	403	2.49	1.18	0.15	1.51	Mg-1	4.04	0.97	0.20	4.01
2 -2 -3	414	2.21	0.83	0.11	1.51	Mg-1	4.00	0.65	0.17	4.06
2 -3 -1	323	1.87	0.82	0.19	0.77	K-1	2.99	1.20	0.70	1.95
2 -3 -2	343	1.57	0.77	0.21	1.00		2.55	0.97	0.56	2.39
2 -3 -3	295	1.49	0.84	0.20	1.22		2.53	0.88	0.42	3.20
2 -½-2	444	2.36	1.14	0.09	0.98	Mg-2	3.94	0.85	0.15	3.99
2 -1½-2	468	2.36	1.09	0.10	0.87	Mg-1	4.25	1.09	0.18	3.50
2 -2½-2	431	2.47	0.66	0.16	0.69		4.13	0.80	0.37	2.67
2 -3½-2	348	1.56	0.77	0.20	0.76		2.82	0.76	0.47	2.27
½-2 -2	229	0.92	0.76	0.18	0.85		2.08	0.67	0.32	2.27
1½-2 -2	307	1.31	0.89	0.19	1.58		2.47	0.72	0.27	3.37
2½-2 -2	385	2.35	1.47	0.10	0.92		3.82	1.33	0.22	2.40
3 -2 -2	315	1.58	1.78	0.10	0.92	S-1	2.66	1.64	0.20	2.19
3 -2 -3	367	1.28	1.62	0.09	1.31	S-2	3.27	1.58	0.16	3.54
3 -3 -2	348	1.61	1.39	0.15	1.03	S-1	2.75	1.79	0.36	2.58
3 -3 -3	397	2.32	1.43	0.15	0.81	S-3	3.60	1.56	0.30	4.10

*Each figure is a mean of four plants analyzed separately.
**Symbol Mg or K denotes type of deficiency occurring on leaves.
Letter S denotes leaf scorch thought to be due to high salt concentration.
Numerals 1, 2, 3 indicate mild, moderate and severe symptoms respectively.

a high level of supply of the other cation and corresponding high concentrations in the tissue. Mg deficiency was the most common and was induced, or increased in severity by increasing the K supply. Fig. 5 shows a typical case where the Mg deficiency was induced by potassium.

Treatments containing Mg_3K_1 were the only ones showing K deficiency symptoms. The plants of other K_1 treatments apparently accumulated enough K at this low level of K supply (or failed to accumulate enough Mg) to prevent the marginal scorch. The plants showing this marginal scorch symptom always had a high Mg content.

It is of interest to note that when both the K and the Mg supply was low, no leaf deficiency symptoms appeared, but plant growth and dry weight were considerably less. As the K supply was increased, the dry weight, stem elongation and the K content increased, the Mg content decreased and almost complete defoliation resulted. Nearly all leaves on these pants showed typical Mg deficiency symptoms.

FIG. 5. The effect of increasing the K supply on the appearance of Mg-deficiency symptoms in young McIntosh apple trees grown in sand culture. Left to right; $Ca_2Mg_1K_1$, $Ca_2Mg_1K_2$, $Ca_2Mg_1K_3$.

TABLE IIb—COMBINED MEANS FROM TABLE IIa (CATION CONTENT EXPRESSED AS PER CENT OF DRY WEIGHT)

Treatment*	Stems					Leaves			
	Height (Mm)	Dry Weight (Gms)	Ca	Mg	K	Dry Weight (Gms)	Ca	Mg	K
				*2 Levels of Ca and 3 levels of Mg+K**					
Ca_1 (9)	284	1.12	0.78	0.17	1.03	2.41	0.77	0.27	2.42
Ca_3 (9)	314	1.79	1.03	0.13	0.96	3.20	1.03	0.33	2.72
Mg_1 (6)	293	1.37	1.14	0.09	0.99	2.83	0.95	0.18	2.83
Mg_2 (6)	301	1.30	0.99	0.13	0.99	2.58	0.92	0.28	2.56
Mg_3 (6)	344	1.74	0.60	0.23	1.01	3.01	0.82	0.45	2.33
K_1 (6)	259	1.24	1.04	0.15	0.71	2.26	1.17	0.40	1.30
K_2 (6)	319	1.50	0.94	0.17	0.90	2.63	0.92	0.31	2.50
K_3 (6)	360	1.69	0.75	0.14	1.39	3.53	0.61	0.19	3.92
				*3 Levels of Ca and 2 Levels of Mg+K**					
Ca_1 (4)	332	1.39	0.61	0.20	1.16	3.01	0.59	0.26	2.91
Ca_2 (4)	359	1.77	0.89	0.16	1.16	3.02	0.96	0.36	3.16
Ca_3 (4)	357	1.70	1.56	0.12	1.02	3.07	1.64	0.25	3.10
Mg_1 (6)	340	1.44	1.17	0.12	1.17	2.96	1.04	0.21	3.14
Mg_3 (6)	358	1.80	0.87	0.21	1.05	3.11	1.05	0.38	2.97
K_1 (6)	324	1.48	1.09	0.18	0.94	2.59	1.16	0.35	2.34
K_3 (6)	372	1.76	0.95	0.15	1.29	3.49	0.99	0.24	3.77

*The means for all treatments receiving the level of the cation indicated were averaged regardless of the levels of the other two. The numeral in parenthesis indicates the number of treatments so averaged. Thus the data opposite Ca_1 (9) are the means of the nine treatments receiving the Ca_1 level of Ca, those opposite Ca_3 (9) are the means of the corresponding nine treatments receiving the Ca_3 level of Ca, and so on.

Discussion and Conclusions

Under the conditions of this experiment the primary result of deficiency levels of mineral nutrient supply seemed to be that of reduced growth and leaf size. The typical leaf deficiency symptoms (marginal scorch, interveinal chlorosis, and necrosis), which are normally associated with the deficiencies of K and Mg, appeared only in cases of high content of the other cation in the tissue. These symptoms did not appear when both K and Mg were at low supply levels, although almost no growth resulted because of the nutrient deficiency level. When either K or Mg were increased, a leaf injury pattern typical of commonly described deficiency symptoms of the other element resulted.

Since the leaf symptom usually appears after the leaf has made approximately normal growth, and the leaf symptom appears as an injury effect ultimately resulting in death to apparently healthy tissue, it seems to be a logical conclusion that the leaf injury, or symptom, normally attributed to a deficiency of one element (Mg), might actually be a toxic effect produced by an excess of the other element (K).

The distinction between "nutrient" and "balance" with respect to plant nutrient substrates has been pointed out. There is a correlation here in that when both K and Mg were at the low level of supply (.4 and .3 m e/liter respectively) the solution was deficient with respect to nutrient value, resulting in very little plant growth. However, the solution was balanced, and thus no toxicity (leaf injury) resulted. In the case of an increase in the supply of either cation, the solution was increased in nutrient value, resulting in increased growth, but was "unbalanced" and produced a toxic effect (leaf injury, or deficiency symptom) in the leaf.

This interpretation is still debatable because the leaf injury pattern is always associated with a low tissue content of the deficient element, and it is common practice to prevent or cure the deficiency by applications of the element in minimum. However, based on the concept that the low tissue content of the one cation results in the lack of an antagonizer for the toxic effect of the cation in excess, the evidence favors this method of expression. Thus, there may or may not actually be a deficiency of Mg, but the interveinal necrosis may appear upon the accumulation in the leaf of excess potash.

Evidence is presented showing that the reciprocal relationship observed is largely in the leaf tissue and that leaf content does not necessarily reflect total absorption of these cations by the plant. Differences in total absorption, due to differential permeability of the membrane surfaces in the roots, could not account for the observed difference in distribution of these cations between the leaves and stems. Neither could changes in the activity of a given cation, due to changes in total ionic strength, account for apparent differences in absorption. On the other hand it appears that the increased absorption and accumulation in the leaf of one cation, when there is a deficit of another, occurs as a result of unsatisfied total cation requirement in the plant.

It is suggested by way of speculation that leaves could have a "cation

requirement" or capacity for total cations, which may be satisfied by two or more cations. This value would, of course, vary with the growth and physiological development within the plant. This condition could be provided for by hydrophyllic and amphoteric colloidal material in the cell sap, residual electrostatic valence on membrane surfaces, or by some other mechanism within the tissues. This mechanism would, in part, explain some of the observed cation behavior encountered by the plant analyst.

It has been pointed out that there is no apparent chemically equivalent exchange indicated by the data here. Other cations (Na, Fe, Mn) not determined, together with differences in cation capacity between plants may possibly account for the observed differences on an equivalent basis. Further evidence on this behavior is necessary before conclusive deductions can be made.

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Some Effects of Season, Fruit Crop and Nitrogen Fertilization on the Mineral Composition of McIntosh Apple Leaves[1]

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The use of leaf analysis for both research and diagnostic purposes in the study of plant nutrition has come into widespread use within recent years. Boynton and Compton (7) have pointed out a number of factors influencing the mineral composition of apple leaves and indicated a number of precautions that should be observed in sampling and in the interpretation of leaf analysis data in terms of nutrient requirements and tree response.

Probably one of the most difficult of these factors to take into consideration is the influence of one fertilizer element on the leaf content of another. A number of investigators (1, 3, 5, 8, 9, 15, 16) and others have reported increases or decreases in the tissue content of one nutrient as a result of applications of another. These interactions are variously referred to as "antagonism," "ion competition" and "nutrient balance" (2).

In view of the relatively widespread and continuous use of nitrogen fertilizers alone in New York apple orchards, it was thought to be of considerable importance to study the effect of continuous nitrogen fertilization on the leaf content of other nutrients.

Boynton and Compton (6) reported significant decreases in K and P and increases in Ca and Mg in the leaves of McIntosh apple trees in the summer after two successive years of ammonium sulfate applications in the spring. The present paper summarizes the results of a continuation of the study of these relationships in two of the orchards (Shannon and Forrence) reported on by the above investigators, after 4 years of continuous treatment.

In laying out the experiment, sets of three trees each were matched for size and vigor and three increments of commercial ammonium sulfate applied annually in the spring. All treatments were randomized over the orchard block so as to eliminate differences due to soil variation and tree position. Only the trees receiving continuous treatment from 1942 to 1945 inclusive were used in this study. Table I summarizes descriptive data for these orchards.

During the 1944 and 1945 growing season leaf samples consisting of 30 mid-shoot leaves per tree were taken every 2 weeks in the Shannon orchard and monthly in the Forrence orchard from the time the trees were in full leaf until after harvest. The samples were dried and ground in the conventional manner and analyzed for Ca, Mg, K and P according to the general procedure of Peech (13) as modified for plant material by Cain (2). Total nitrogen was determined by the Kjeldahl method.

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[1] Journal paper no. 738; New York State Agricultural Experiment Station, Geneva, N. Y.

TABLE I—DESCRIPTION OF ORCHARDS

Item	Shannon Orchard	Forrence Orchard
Location	Western New York	Champlain Valley
Soil type	Dunkirk very fine sandy loam	Dover loam
Cover maintained	Light sod	Heavy sod
Drainage	Imperfect	Good
Age in 1942	20 years	17 years
Variety	McIntosh	McIntosh
Number trees per treatment	8	12
Treatment (pounds of ammonium sulfate per tree)	2.5 5.0 7.5	None 5.0 10.0

RESULTS

The tabulated data are shown for both orchards in Table II expressed as milli-equivalents per 100 grams of dry leaf tissue. These data for the Shannon orchard are shown graphically in Figs. 1 to 3 accompanying the discussion.

The effect of Nitrogen and Sampling Date:—In order to more clearly see the effect of the successive increments of nitrogen on the composition of the leaf tissue, each constituent determined is plotted against the nitrogen application in Fig. 1. Only the 1944 Shannon orchard data are shown in this form, but the same general trends are shown by the data from both orchards for both years (Table II).

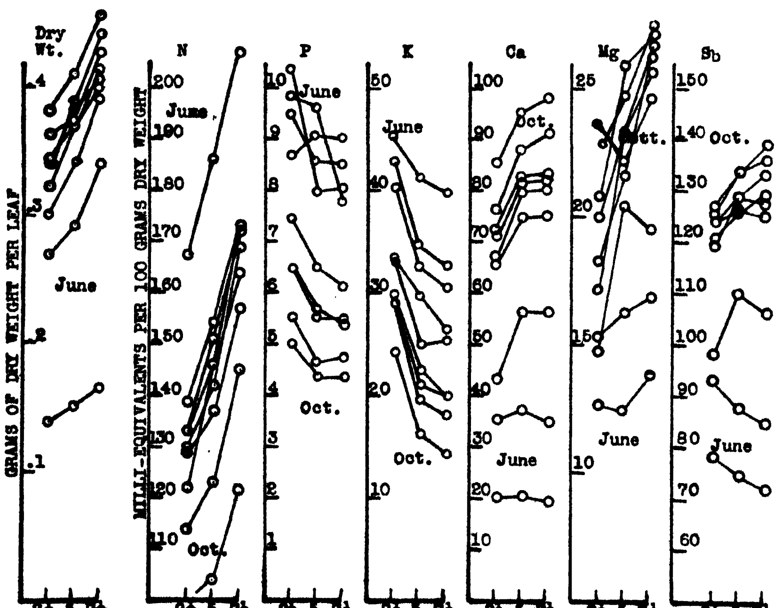

FIG. 1. The effect of annual spring applications of ammonium sulfate on the mineral composition of the foliage of McIntosh apple trees. Each curve is a separate sampling date during the growing season (Shannon Orchard, Wayne County, New York). Note: S_b = Sum of bases (Ca + Mg + K)

TABLE II—THE EFFECT OF DATE OF SAMPLING, FRUIT CROP AND ANNUAL APPLICATIONS OF AMMONIUM SULFATE ON THE MINERAL COMPOSITION OF MCINTOSH APPLE LEAVES (EXPRESSED AS MILLI-EQUIVALENTS PER 100 GRAMS OF DRY WEIGHT)*

Date Samples	Dry Weight**	N	P	K	Ca	Mg	S_b†	Dry Weight	N	P	K	Ca	Mg	S_b	Dry Weight	N	P	K	Ca	Mg	S_b
Shannon Orchard (1944) (Heavy Crop)																					
	2.5 Pounds Per Tree							5.0 Pounds Per Tree							7.5 Pounds Per Tree						
May 30	140	168	9.8	45.3	20.9	12.8	79	155	186	9.6	41.4	21.3	12.2	75	168	207	7.7	39.4	19.3	13.9	73
Jun 13	270	122	10.3	42.7	36.0	15.3	94	295	146	7.9	34.3	37.5	16.2	88	342	173	8.0	32.5	35.6	16.9	85
Jun 27	303	133	9.5	40.4	43.2	14.7	98	342	151	8.5	32.5	56.9	20.6	110	393	172	8.5	31.0	56.4	19.5	107
Jul 11	342	139	8.7	33.5	65.9	23.6	123	371	154	9.1	29.9	74.4	21.6	125	405	173	9.0	26.9	73.9	24.5	125
Jul 25	325	130	7.5	33.0	66.9	22.9	123	370	142	6.5	24.8	78.8	24.8	128	429	169	6.2	25.6	79.8	27.4	133
Aug 15	337	129	6.5	28.9	71.4	20.0	120	391	137	5.6	21.5	81.8	23.2	127	440	157	5.5	20.0	81.8	26.5	128
Aug 31	338	133	6.5	29.7	75.9	20.8	126	381	146	5.7	19.7	87.8	25.8	133	409	164	5.4	18.4	90.3	26.9	136
Sep 22	363	114	5.3	29.9	71.9	17.4	119	375	123	4.7	22.8	82.3	23.3	128	416	145	4.8	19.2	82.3	25.6	127
Oct 30	383	99	5.0	24.3	84.8	18.1	127	411	104	4.4	16.6	94.3	22.1	133	458	122	4.4	14.8	97.3	26.0	138
Shannon Orchard (1945) (No Crop)																					
May 16	—	178	13.0	38.6	37.4	21.1	97	—	198	11.3	37.9	33.4	17.4	89	—	201	11.3	31.7	31.4	17.9	81
Jun 1	256	160	7.8	46.0	31.9	16.1	94	276	188	6.9	42.2	29.4	15.1	87	275	191	6.8	40.7	28.4	15.9	85
Jun 14	296	134	7.9	41.7	40.4	16.8	99	333	159	6.8	34.0	40.4	18.8	93	343	167	6.1	39.7	37.4	20.2	97
Jun 28	266	131	6.7	47.1	48.4	21.1	117	308	142	5.8	29.7	48.4	22.0	100	330	162	5.7	31.7	47.9	23.1	103
Jul 12	290	121	7.1	38.6	51.9	20.9	111	317	139	6.2	33.0	52.4	22.4	108	355	155	6.1	30.2	50.9	22.6	104
Aug 9	329	115	7.6	42.2	55.9	21.1	119	363	129	6.4	32.2	60.9	22.4	115	413	144	5.9	34.8	59.4	22.9	117
Sep 20	332	102	7.4	41.7	61.4	21.3	124	374	111	5.8	34.8	65.9	23.1	124	408	124	5.7	32.0	65.9	25.3	123
Oct 19	333	95	6.3	34.3	68.9	18.1	121	373	104	5.2	27.4	73.4	22.3	123	384	116	5.0	27.4	72.4	23.5	123
Forrence Orchard (1944) (Normal Crop)																					
	None							5 Pounds Per Tree							10 Pounds Per Tree						
Jun 6	198	114	9.5	47.6	32.4	20.7	101	241	155	8.8	39.1	32.9	21.0	93	234	159	8.4	38.6	32.9	21.3	93
Jul 12	286	111	8.2	43.0	52.9	21.6	118	371	161	6.0	32.7	63.4	22.5	119	390	169	5.8	30.2	60.4	22.5	113
Aug 10	324	113	9.4	42.0	60.9	20.6	124	416	154	5.8	28.4	75.3	24.2	128	427	160	5.6	26.1	76.4	28.1	131
Sep 19	282	109	9.2	35.6	64.4	20.2	120	405	146	5.0	24.1	77.4	23.4	125	430	154	4.6	21.0	74.4	28.2	124
Forrence Orchard (1945) (No Crop)																					
Jun 13	220	149	8.4	62.7	38.9	19.7	121	240	174	7.5	53.0	32.4	18.1	104	336	181	7.3	46.0	30.4	21.0	98
Aug 1	283	139	9.5	52.7	57.9	21.5	132	316	161	6.6	42.0	56.4	23.5	122	322	173	5.7	38.4	59.4	26.2	124
Sep 10	281	127	10.1	51.7	57.4	17.3	126	316	147	5.6	43.2	60.4	21.4	125	324	161	5.4	39.4	63.9	23.6	127
Oct 8	281	116	10.3	44.5	62.9	16.8	124	316	133	5.0	35.6	68.9	20.2	125	323	143	4.6	31.0	68.4	23.0	122

*Phosphorus considered as monovalent ion.
**Dry weight in milligrams per leaf.
†S_b = sum of bases (Ca + Mg + K).
Note: Each figure in the table is the mean of four determinations, each consisting of a composite of two trees in the Shannon and of three trees in the Forrence orchard.

Leaf weight increased rapidly with increased nitrogen supply, tending to level off with the higher applications in the Forrence orchard. This indicated that further response in leaf weight might be expected with additional nitrogen in the Shannon orchard but not in the Forrence orchard.

Phosphorus was reduced as much as 30 per cent of its initial value by the first increment of nitrogen in the Forrence orchard. The effect of reducing the P content of the leaves was noticeable throughout the season in both orchards, but to a lesser extent in the Shannon orchard which received smaller increments of the fertilizer. The data indicate that the decrease in leaf phosphorus per pound of amonium sulfate applied was about the same in both orchards, being from .4 to .6 me/100 grams of dry leaf tissue at the lower nitrogen levels and somewhat less at the higher nitrogen levels. The effect was slightly more pronounced in the early part of the growing season than later.

The effect of nitrogen supply on the K content of the leaf was similar to its effect on P. The reduction in the K content of the foliage was from 1.5 to 2.0 me/100 grams of dry leaf tissue for each pound of ammonium sulfate applied at the lower levels, the amount of reduction decreasing as the rate of nitrogen application increases. Both P and K decreased in the leaf as the season advanced, the extent of which is increased by nitrogen.

Calcium and magnesium were both unaffected or slightly decreased in the leaves by nitrogen in the early part of the season, but were markedly increased as the season progresses. The decrease in the leaf content of these cations in the early part of the season was probably largely due to the increased rate of growth as a result of nitrogen fertilization. The rate of absorption and translocation of these less mobile cations apparently did not keep pace with the increases in growth rate. This can be more clearly seen in Fig. 2 where the values are plotted against season. If leaf weight is taken into consideration the total amount of calcium and magnesium was greater in the high nitrogen trees throughout the season, but the concentration of these elements in the high nitrogen leaves did not surpass that of the low nitrogen leaves until the growth rate slows down. This is more noticeable in the case of calcium.

In 1944 the sum of bases (Ca+Mg+K) was less in the high nitrogen trees early in the season, reflecting again the period of rapid increase in dry weight of the leaves. However, this value increased rapidly during the season, becoming greater in the high nitrogen trees at about the time of cessation of terminal growth, indicating that the combined increases of calcium and magnesium were greater than the decrease of potassium, the difference increasing as the season advances (Figs. 1 and 2).

Leaf nitrogen increased sharply with its supply, the curves indicating that further increases in leaf nitrogen would be expected with additional increments of supply. The nitrogen content followed the leaf weight response closely with respect to nitrogen supply, but reversed with respect to season; that is, the nitrogen content of the leaves de-

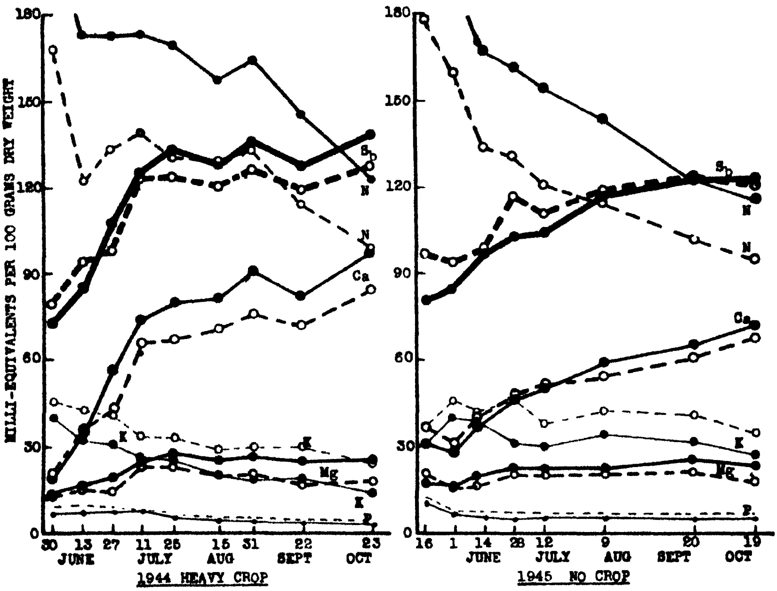

FIG. 2. The effect of annual spring applications of ammonium sulfate on the mineral composition of the foliage of McIntosh apple trees. Solid line, 2.5 pounds/tree; broken line, 7.5 pounds/tree (Shannon Orchard, Wayne County, New York).

creased during the growing season and leaf weight increased (Figs. 1 and 3).

It is seen that Ca, Mg and sum of bases increased in concentration rapidly early in the season until the approximate time of cessation of terminal growth, after which they tend to level off with only very slight increases for the remainder of the season. It is of interest to note that the direction of change in concentration of each element in the leaf during the growing season is the same as with increasing nitrogen supply, that is, Ca and Mg increase whereas K and P decrease.

Discussion:—The results for the effect of nitrogen on the mineral content of the leaf in mid-season confirm the earlier reports of Boynton and Compton (6). It is also shown that these effects generally hold throughout the season except for the reverses in the case of calcium and magnesium in the early part of the season, which can be attributed to the low mobility of these cations, and the period of rapid growth of leaves and shoots.

Peech and Bradfield (14) have shown that more potassium is tied up in the soil exchange complex as the degree of calcium saturation is increased. It would not be expected that the ammonium ion would have this effect on potassium. On the contrary, ammonium ions should release potassium from the soil exchange complex. However, it was shown by these investigators that the increased presence of exchangeable hydrogen decreases the hydrolysis of K-clay in the absence of

neutral potassium salts. Since the primary source of K in these mineral orchard soils is that of the residual clay mineral (no potash fertilizer having been used), the available soil potassium may be reduced by this reaction, as a result of the acidifying nature of the fertilizer material. Nitrification and differential absorption of the ammonium ion over that of the sulfate ion by the plant would tend to increase the exchangeable hydrogen in the soil with continued use of ammonium sulfate as a fertilizer. The reduced hydrolysis of the K-clay would then result in a reduction in the rate at which the exchangeable potassium is renewed in the soil from non-exchangeable sources. This effect, although of interest as a contributing factor is probably not large enough under the conditions of this experiment to account for the observed decrease in the potassium content of the foliage.

Since calcium and magnesium are the predominant cations in the exchange complex, and also these cations are frequently present as the free carbonates in these soils, it might be expected that Ca and possibly Mg would become more available to the plant under the above conditions. However, this point would have to be further checked by both plant and soil study under controlled conditions.

Although increased vegetative growth, under conditions of limited mineral nutrient supply, could account for decreased concentrations of minerals in the foliage, these data indicate that potassium and phosphorus are decreased more than can be accounted for by increased leaf weight. Calcium, magnesium and total bases are shown to increase with increased nitrogen supply. Thus, even considering that leaf growth does not adequately represent the entire growth of the tree, the growth factor cannot explain the increases in the concentration of the latter nutrients in the foliage.

Since growth cannot account for increases in one cation and simultaneous decreases in another, the soil interaction does not adequately explain all of these relationships, and it is difficult to attribute these reciprocal relationships to ion competition at the absorbing surface of the root, the only alternative is to assume that the *distribution* of these cations within the plant is in some way affected by the nitrogen supply. If this be true, the analysis of leaves alone does not accurately portray the nutrient status of the plant as a whole. Neither would the analysis of one nutrient necessarily indicate a deficiency of that nutrient in the plant as a whole.

Although leaf analysis has been proven successful in the diagnosis of deficiency levels in many cases, the interpretation of such data should include a consideration of the changes occurring in other elements besides the one whose deficiency is indicated. Thus, a deficiency level of potassium in the leaf does not necessarily imply that an application of potassium to the soil is the most profitable corrective measure. A shift in balance, or distribution may be obtained by other measures.

The Effect of Fruit Crop:—The effect of fruit crop can be seen by comparing the data for 1944 with those for1945 (Figs. 2 and 3). The latter graph shows only the data from the high nitrogen trees for both years. In 1944 the trees had a fairly good crop, but in 1945 the total crop was lost because of a freeze at blossom time.

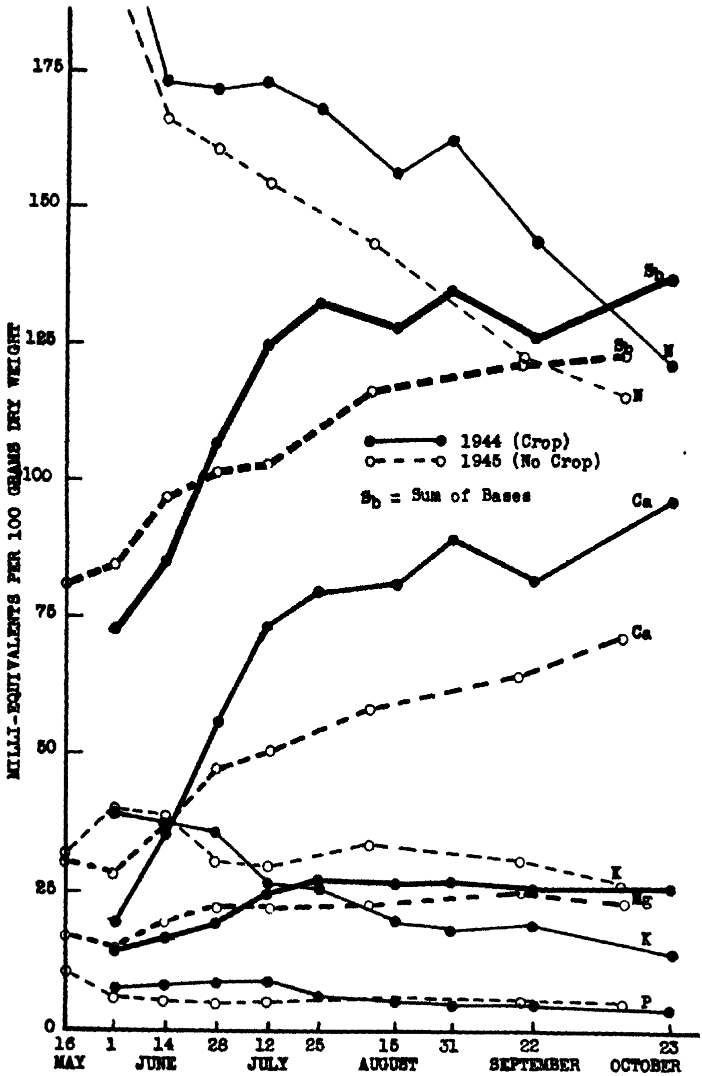

FIG. 3. The effect of fruit crop on the mineral composition of the foliage of McIntosh apple trees. All trees received 7.5 pounds of ammonium sulfate annually since 1942.

It will be seen from the graphs that the changes in the concentration of each nutrient in the leaf as affected by the fruit crop (Fig. 3) are in the same direction as those affected by increasing the nitrogen supply (Fig. 2). That is, both fruit crop and nitrogen fertilizer caused de-

creases in potassium and phosphorous and increases in calcium and magnesium.

Although the calcium and magnesium content of the foliage was greater in the high nitrogen trees during both years, the increase in these cations was less during the no crop year, resulting in a lower value for the sum of bases in the high nitrogen trees. In other words, the combined increase of calcium and magnesium was less than the increase in potassium in the leaves during the no crop year. The reverse of this was true during the crop year.

The nitrogen content of the leaves is higher in both orchards earlier in the season of the no crop year (1945), but falls rapidly and remains lower than that of the corresponding trees during the crop year for most of the growing season.

Discussion

It is questionable whether or not these results represent a true picture of the effect of fruit crop on the mineral content of the foliage, especially with reference to alternate bearing trees. These trees had differentiated a crop of fruit buds the previous season and blossomed normally in the spring of 1945. In the case of alternate bearing trees the fruit buds would not have been differentiated during a crop year.

Since the results were essentially the same in both orchards, differences due to soil moisture, soil type and geographical location can be eliminated, as they were quite different in the two orchards. Rainfall was considerably heavier in Western New York and the Shannon orchard was quite wet in the summer of 1945. However, the Forrence orchard was well drained and a heavy grass cover helped eliminate any excess water that may have prevailed in this location. Thus, differences in the degree of nitrification, aeration and accompanying soil reactions could not have been dominant contributing factors.

Heinicke (10) has reported data which indicated that potash increased in the fruit buds and decreased in the leaf tissue with increasing nitrogen supply. There were also great increases in nitrogen in the fruit buds from the time of differentiation until the spring prior to blossoming. Howlett (12) has shown large increases in nitrogen in the flowers and young fruit at the time of fruit setting, but in the case of unpollinated flowers a considerable amount of the nitrogen returns to the cluster base prior to abscission. Hopkins and Gourley (11) have shown that McIntosh fruit contain relatively large amounts of potash and that this increases as the season advances.

In view of these findings, a possible explanation can be derived for the observed effect of fruit crop on the nitrogen and potassium in these experiments. During the crop year (1944) relatively large amounts of potassium were possibly being taken by the fruit crop resulting in less potassium in the foliage. Since a larger fruit crop resulted from the nitrogen fertilization (6), this would also explain the effect of nitrogen in reducing the potassium in the leaf. The reduced potassium in the leaves consequently results in increased accumulation of Ca and Mg by this organ to satisfy its cation requirement.

In 1945 the trees blossomed normally but the essential flower parts

were sufficiently killed by the freeze to prevent fertilization. If the nitrogen in the flowers thus killed behaved in the same manner as when flowers fall as a result of pollination failure, a considerable amount of the nitrogen in them moved back into the cluster base immediately following the freeze. This would result in higher nitrogen in the leaves early in the season of the no crop year (1945) as was observed. Due to the crop loss, an unusually heavy crop of fruit buds was differentiated in late June or early July of the 1945 season, as was verified by the unusually heavy bloom in 1946. The nitrogen required for the growth and development of these fruit buds possibly caused the observed rapid decline in the nitrogen content of the leaves during this season. The lack of a fruit crop on the trees in 1945 resulted in a higher potassium content of the foliage during this season.

Whether or not calcium and magnesium accumulate in the fruit buds and in what proportion relative to potassium and nitrogen is not known. Further investigation is necessary to determine the relative distribution of the various minerals within the apple tree, both with respect to differentiation and development of the fruit buds and also as affected by the growth and maturing of the crop of fruit.

It is of further interest to note here that the three factors studied, namely fruit crop, nitrogen supply and growing season, all affected the mineral content of the foliage in the same way; that is, reduced potash and phosphorus, and increased calcium, magnesium and total bases. The latter resulted from a greater increase in calcium and magnesium than reduction in potash.

Summary and Conclusions

1. Leaf analysis data are presented from two experimental apple orchards, rather widely different as to climate and soil type, each having received differential applications of ammonium sulfate for 4 consecutive years.

2. The data indicate marked decreases in leaf potassium and phosphorus and increases in calcium, and magnesium and total bases (Ca + Mg + K): (a) as the nitrogen application is increased, (b) as the growing season advances, and (c) with a heavy crop of fruit.

3. Although certain soil reactions and growth factors are pointed out as possible contributing factors in causing the observed results, reasons are given leading to the possibility that these changes in the mineral composition of the foliage are partly due to changes in the distribution of these minerals within the plant.

4. Further investigation into the distribution of mineral nutrients within the fruit tree at various stages in its physiological development are suggested.

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Nitrogen Fertilization of the McIntosh Apple with Leaf Sprays of Urea

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One of the major problems in the production of the McIntosh apple in New York is the regulation of the nitrogen level to obtain satisfactory yields of well colored high quality fruit. In 1939, Hamilton and Palmiter (2) commenced experiments in the Hudson Valley region of New York to determine the effect of various nitrogenous compounds applied with the regular sulfur scab sprays on apple trees. They found that urea caused no apparent injury to the foliage at a concentration of 5 pounds to the hundred gallons, and that applications at that concentration caused a very rapid increase in the green color or chlorophyll of the leaves. They published some preliminary results in 1943 (2) and have continued their work since then. This work (unpublished) seems to indicate that leaf sprays can maintain an apple tree in an apparently satisfactory level of nitrogen nutrition. Their experiments thus far have suggested the usefulness of urea sprays in solving special problems of nitrogen fertilization where control of amount and timing may be of paramount importance. Among such problems is the fertilization of McIntosh apple trees for maximum quality and productivity.

The present experiment has two purposes: (a) to determine what the effects of varying nitrogen levels and methods of application, that is soil and sprays, may be on the yield and quality of the McIntosh apple, and (b) to determine what practical value urea sprays may have in orchard nutrition.

Method

Six treatments were selected as follows:

Treatment A—Three sprays of urea

Concentration: 5 pounds to the hundred gallons

Rate: 20 gallons, or about 1 pound of urea per tree per spray, or a total of about 3 pounds of urea.

Time: When the experiment was started it was assumed that insufficient leaf area would be available prior to the petal fall stage for leaf sprays to be effective. Consequently, applications were made at the petal fall and first two cover sprays. (Current experiments to be mentioned shortly proved this assumption in error).

Treatment B—1½ pounds of urea on the soil in the early spring (first part of April).

Treatment C—6 sprays of urea consisting of a petal fall and the first five cover sprays (total 6 pounds of urea); otherwise similar to to treatment A.

Treatment D—Treatment B plus treatment A, that is, 1½ pounds of urea on the soil in the early spring plus three sprays commencing in the petal fall stage.

Treatment E—3 pounds of urea on the soil in the early spring (first part of April).

Treatment F—No fertilizer check.

There were, therefore, three ground applications at levels of 0.0, 1.5 and 3.0 pounds of urea[1] per tree as compared with spray applications at levels of 3.0 and 6.0 pounds of urea and a soil-spray application of 4.5 pounds.

Fifty-four replications were set up in randomized block arrangement with single tree plots or treatments. There were three locations: orchard I consisted of 20 replications and was located at West Webster, New York; orchard II consisted of 20 replications and was located at Sodus, New York; orchard III consisted of 14 replications and was located near Ontario, New York. All the trees were 18 to 20 years old and of the McIntosh variety. Prior to treatment, the trees in each replication were grouped as closely as possible according to trunk diameter, apparent size of top and proximity of location.

The following data were collected: (a) milligrams of chlorophyll per 100 cm^2 leaf area at intervals over the growing season; (b) terminal growth; (c) percentage of all spurs setting fruit; (d) yield; (e) percentage of fruit having 50 per cent or more of the surface covered with a solid red color; and (f) weight of 60 fruit as a rough estimate of the size of fruit.

The milligrams of chlorophyll per 100 cm^2 of leaf area were determined on disks removed from 30 leaves on each tree (1). These leaves were taken from the midsection of the current season's growth. Terminal growth was obtained by measuring 40 terminals per tree in centimeters. Percentage of spurs setting fruit was obtained by classifying a minimum of 200 spurs from each tree — at least 50 spurs from each of the four sides of the tree. Yields were obtained in bushels. The yields of picked and drop fruit were added together to obtain total yield. Sixty fruits were picked at random from the outside periphery of each tree. The fruit was weighed and then separated into the color classes.

Cold and rainy weather prevailed during most of the spring of 1947. The blossoming period for McIntosh was not until the latter part of May and the weather continued cold and wet during this period. For this reason the set of fruit was light and yields averaged only from about 5 to 7 bushels per tree. Scab control was difficult and orchard I was moderately infected. The foliage of orchard III was injured somewhat by early applications of lime sulfur.

RESULTS AND DISCUSSION

Compiled Summary for the Three Experimental Orchards:—The compiled results of the experiments in the three orchards are shown in Table I. The F value due to treatment was far greater than the .01 level needed for significance for every criterion of tree performance obtained. The last column of Table I gives the least difference significant at the .05 level.

[1]Soil applications of urea supplied as Uramon; foliage applications as Nugreen.

TABLE I—COMPILED RESULTS OF THE EXPERIMENTS IN THE THREE ORCHARDS

	Treatments						F (3) Value	0.05 Level	0.01 Level	L.S.D. 0.05 Level
	F	A	C	B	E	D				
Mg Chlorophyll 100 cm^2 leaf area	2.019	2.298	2.316	2.188	2.440	2.612	27.32	2.26	3.11	0.106
Terminal growth in cm	15.4	16.6	17.1	17.4	19.0	19.5	8.72	2.26	3.11	1.4
Percentage of spurs setting fruit	13.7	13.4	15.1	16.6	19.9	19.3	10.01	2.26	3.11	2.5
Yield in bushels	4.91	4.86	4.64	5.25	6.78	7.16	10.06	2.26	3.11	0.9
Percentage of fruit having 50 per cent color or over	82.5	64.8	46.8	70.6	56.5	55.9	19.85	2.27	3.14	7.9
Weight of 60 fruit in pounds	16.8	18.7	19.4	17.7	18.3	19.0	22.22	2.27	3.14	0.6

A bar graph of the above treatment averages is given in Fig. 1. The chlorophyll depicted is an average of the three different locations taken around July 1st, prior to which time only two sprays had been given to treatments A, C, and D.

The treatments were comprised of three components which might affect results; (a) amount of nitrogen applied; (b) method of application, that is, soil or spray; and (c) time of application. In this grand summary of the orchards (Fig. 1) it is evident that an increase in the level of the ground urea application (treatment F 0.0, treatment B 1.5, and treatment E 3.0 pounds) caused a corresponding increase in chlorophyll per unit area and an increase in terminal growth, set, yield and fruit size, and a corresponding decrease in fruit color.

Three pounds of urea applied to the soil in the early spring (treatment E) produced more chlorophyll per unit leaf area by July 1st and also produced greater terminal growth, set and yield than 3 or 6 pounds of urea applied as a spray commencing at the petal fall stage (treatments A and C).

Treatment E also was about equally as effective in increasing terminal growth, set and yield as 1½ pounds of urea applied to the soil in the early spring plus three sprays, a total of 4½ pounds of urea (treatment D).

Since the spray treatment A received the same amount of urea and treatment C more urea than treatment E, the differences in results are not due to the amount of application, but may be due to either or both the method of application and the time of application. These spray treatments went through almost a month of active growth before nitrogen was applied to the trees. This delay undoubtedly accounted for some of the decreased terminal growth, set, and yield. It is also possible that some of the urea applied as a spray was washed off by rain. The orchards were in sod and nitrogen washed off during the growing season was probably rapidly assimilated by grass roots.

Whatever the nitrogen treatment, fruit color was greatly reduced. The no fertilizer check had much better color than any other treatment. Color was reduced the greatest extent by spraying up till the middle of August (6 pounds of urea — spray C treatment). Treatment B with 1½ pounds of urea applied in the early spring produced the

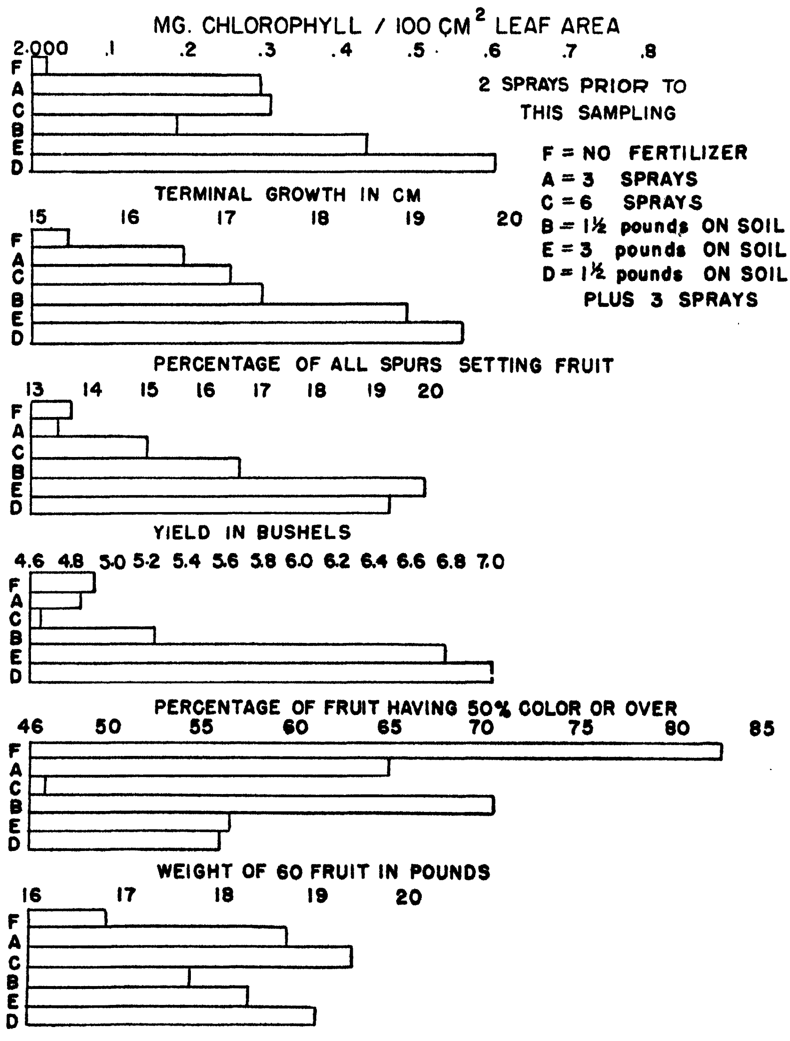

FIG. 1. Grand summary.

second most highly colored fruit. The fact that treatment A with three sprays (3 pounds of urea) produced somewhat better colored fruit than treatment E with the 3 pounds on the soil in the early spring again suggests that all of the nitrogen applied as a spray was not immediately available to the tree.

The three treatments producing the heaviest and, undoubtedly, largest fruit were A, C, and D, the three spray treatments of the experiment. The treatment producing the largest fruit was C which received sprays until middle August. Chlorophyll data showed leaf

sprays to rapidly increase chlorophyll content; possibly leaf sprays increased the photosynthetic efficiency of the leaves also and thus increased fruit size at least under low tree yield conditions.

Results from the Experimental Orchards Considered Separately:— The data for the three orchards taken separately were, in general, very similar to the grand summary. Fig. 2 depicts the data for orchard I. Disregarding for the moment the G treatment, treatments E and D had more chlorophyll per unit area, produced greater terminal growth, set and yield than the other treatments and the picture for fruit color and size is also very similar to that for the grand summary (Fig. 1).

There was some variation in results among the three orchards, however. At orchards I and II (Figs. 2 and 3) treatment C seemed to pro-

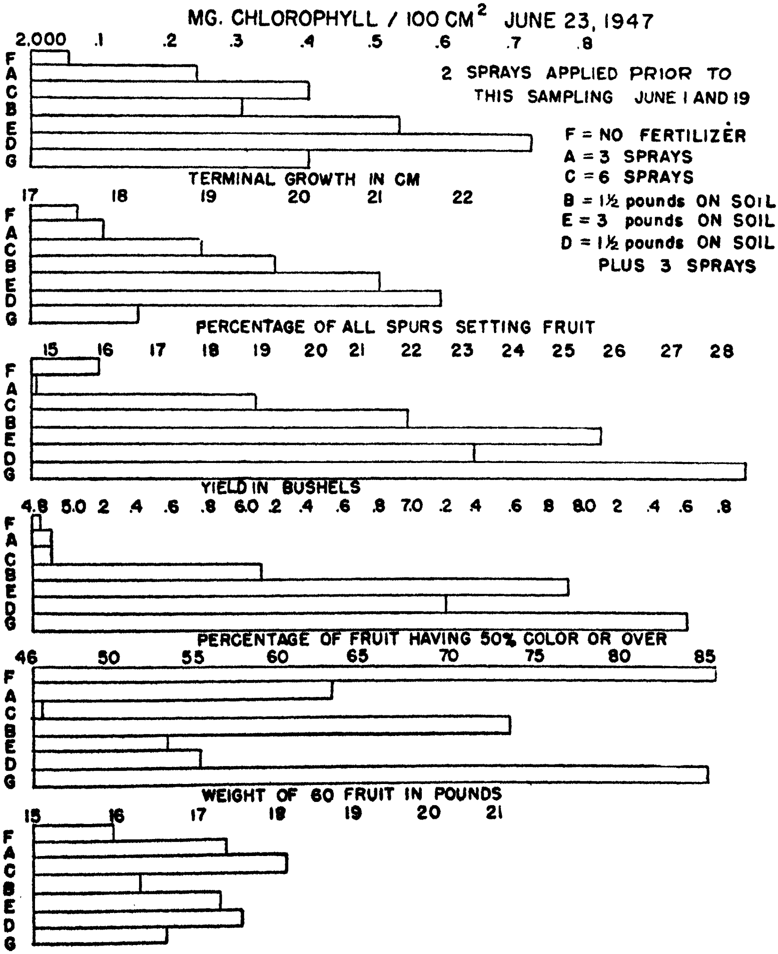

FIG. 2. Orchard I.

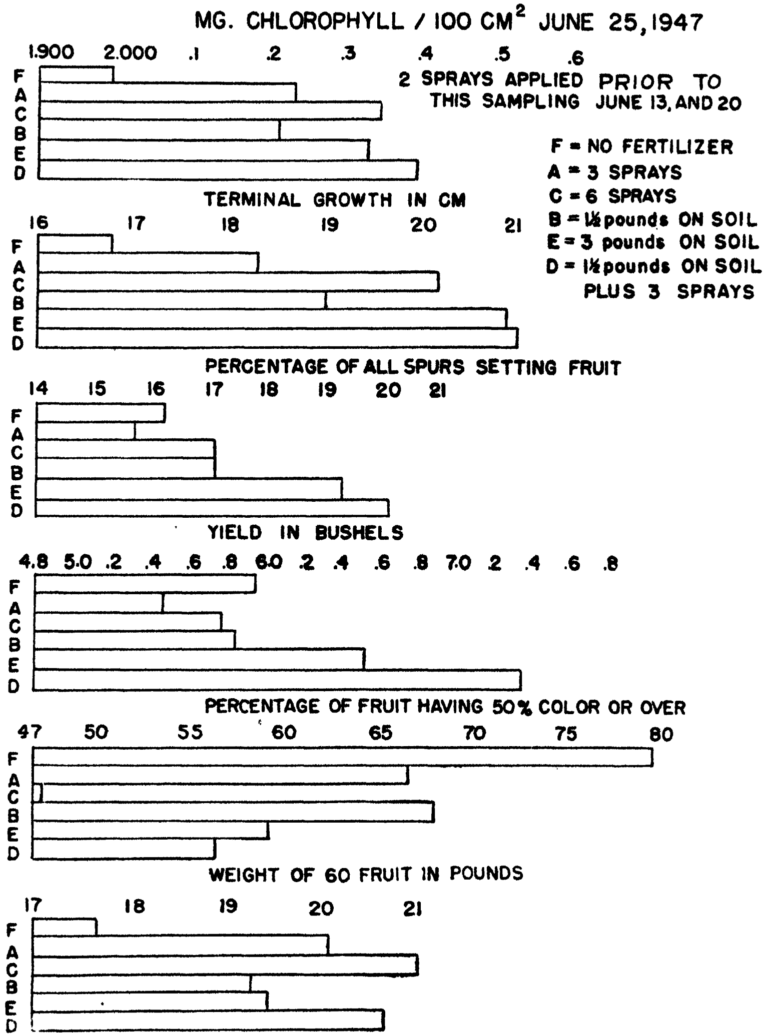

Fig. 3. Orchard II.

duce more chlorophyll by July, greater terminal growth, set and yield than treatment A, but at orchard III (Fig. 4) the situation was reversed. That this was due to the condition of the trees prior to treatment is evident from the cholorphyll data. At orchard II (Fig. 6) the petal fall spray application was about 10 days late. For this reason, the June 12th chlorophyll sampling was previous to any spray treatment. Thus, at this time, no nitrogen had been applied in any form to plots

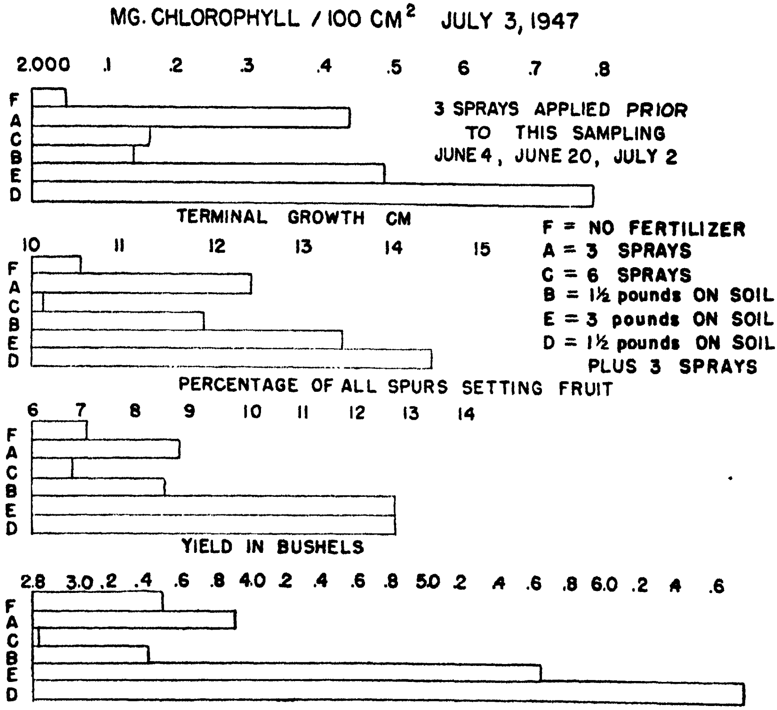

FIG. 4. Orchard III.

F, A, or C, yet treatment C had more chlorophyll per unit area than treatment A. The treatment applied to plots A and C was exactly the same until July 18th, yet the original difference in chlorophyll was maintained on the June 25th and July 11th samplings. The same was true for the June 23rd and July 10th chlorophyll samplings at orchard I (Fig. 5) and the situation was reversed at orchard III. Apparently, therefore, the 20 replications did not level out differences in tree vigor among trees grouped originally according to trunk diameter and apparent size of top.

Orchard II was initially high in nitrogen level and orchard III was low; these differences persisted during the 1947 season and probably influenced the magnitude of response to the treatments given in any orchard.

The Effect of Spraying Urea Prior to Full Bloom, at Petal Fall, and in the First Cover:—All of the urea sprays considered thus far were applied starting with the petal fall application. In orchard I, treatment G was made in order to study the effects of earlier spraying on set and earlier cessation of spraying on fruit quality. Treatment G consisted

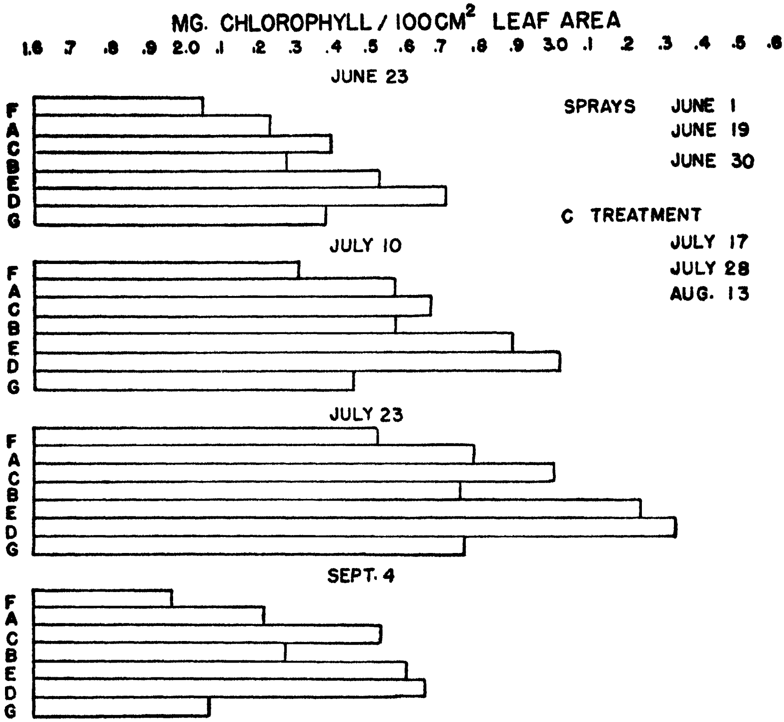

Fig. 5. Orchard I.

of four sprays of urea, two during the late pink stage prior to full bloom, a petal fall and a first cover.[2]

Fig. 5 summarizes the effect of the G treatment on chlorophyll. On June 23rd the G treatment was comparable in chlorophyll to most of the other nitrogen treatments, but by July 10th and from then on until the end of the season, was as low or lower in chlorophyll than any other treatment except the no fertilizer check (treatment F).

Fig. 2 shows the effect of treatment G on the other criteria obtained. Terminal growth was about the same as treatment A or C. However, set and yield were the highest of any other treatment. Heretofore, any nitrogen treatment improving set decreased color, but the G treatment produced fruit with almost as good color as the no fertilizer check.

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[2]There were 20 replications of this treatment at orchard I, but the trees were selected after the original experiment had been set up and were located in the last six rows of the 12 rows of the experiment; hence there may have been experimental errors due to location that do not apply to the original six treatments. The trees, however, appeared outstanding at harvest time compared to the surrounding trees, and the results may be considered of sufficient reliability to warrant further investigation.

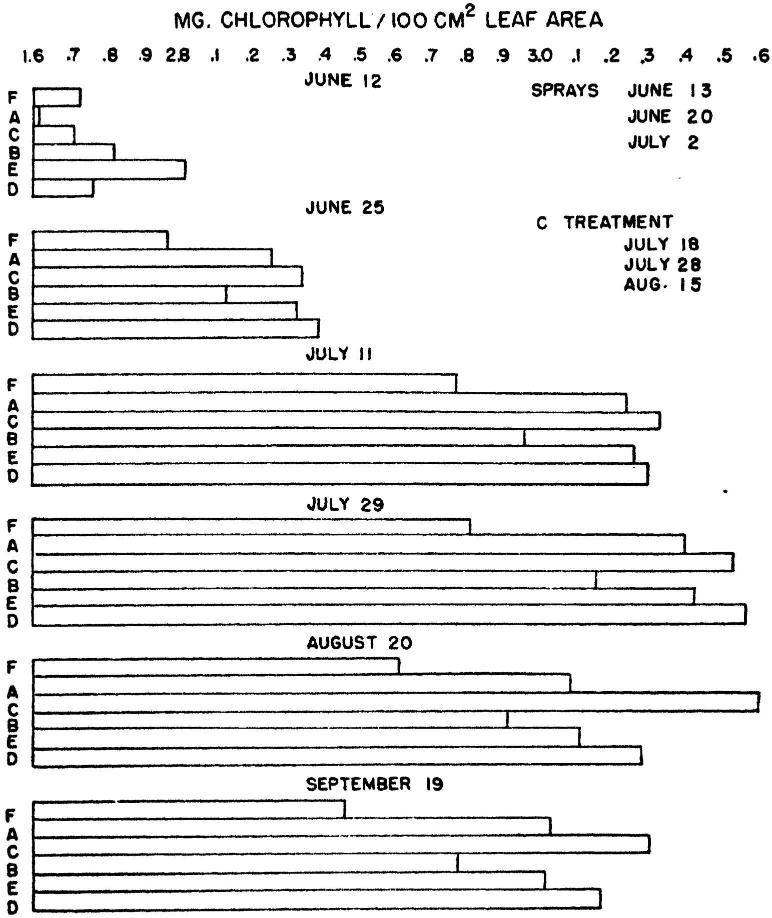

FIG. 6. Orchard II.

SUMMARY

In a year unfavorable for fruit set in three Western New York McIntosh orchards, 3 pounds of urea applied to the soil in the early spring was more effective in increasing terminal growth, set and yield of fruit than was this dosage applied in three sprays commencing at the petal fall stage, but the spray application resulted in slightly better fruit color than the soil application.

In one orchard a treatment consisting of two pre-blossom sprays, a petal fall spray, and a first cover spray appeared to cause a heavier set of fruit than the 3-pound spring soil application; at harvest time the fruit from the trees receiving this treatment had better color than fruit from any trees except those receiving no nitrogen at all.

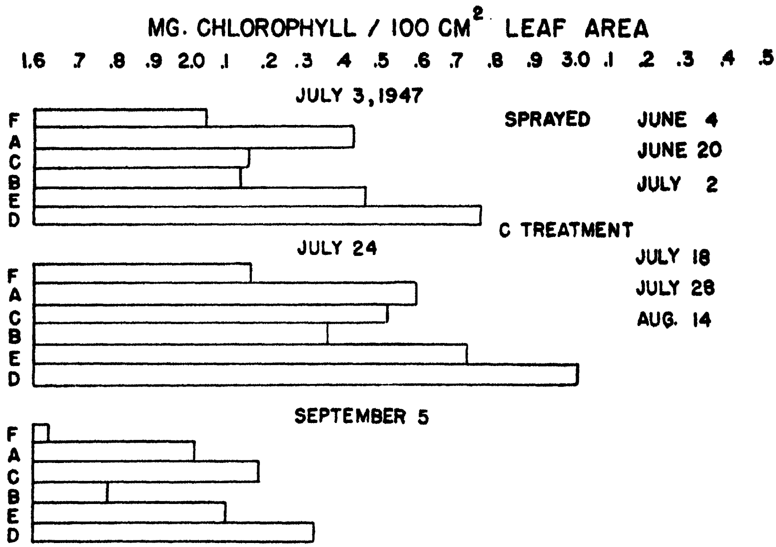

FIG. 7. Orchard III.

Midsummer sprays of urea tended to increase the size of fruit, but they also markedly reduced fruit color.

These results emphasize the fact that the effects of moderate spray applications of urea nitrogen on yield and color of McIntosh apples are dependent on the timing of the sprays as well as on the dosages. They indicate that timing of these sprays may permit better control of fruit set and fruit color, although the commercial value of such practices remain to be seen.

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Carbohydrates in Apple Shoots and Twigs and Their Relation to Nitrogen Fertilization, Yield, Growth, and Fruit Color

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THIS study was undertaken to learn the magnitude of differences in shoot and twig starch and sugars induced by differential nitrogen fertilization of McIntosh apple trees. The studies of Anderson and Hooker (1), Lagasse (3), Stuart (5), Sullivan and Cullinan (6), and Thomas (7) have all indicated that differences in carbohydrates, particularly starch, are likely to exist when fruit trees are growing under different levels of nitrogen.

PROCEDURE

The experimental work was carried out on a block of 23-year-old McIntosh apple trees located in a commercial orchard in Wayne County, New York. The trees were divided into 16 blocks of three trees each on a basis of size and uniformity. The trees have received differential nitrogen fertilization since April, 1942; one tree of each block receiving 7½ pounds, a second 5 pounds, and a third 2½ pounds of sulphate of ammonia in April of each year. The data presented in this paper represent the results of 1947 studies only. These are in all respects similar to those obtained in 1946.

Samples were collected as follows:

DATE	AND GROWTH CONDITION	TYPE OF SAMPLE
Apr 8	Dormant	10 twigs per tree
May 22	Full bloom	10 twigs per tree 10 leafy shoots per tree
Jun 19	Period of rapid shoot elongation	5 twigs per tree
Jul 18	Terminal buds formed on all except isolated high N trees	5 shoots per tree 5 twigs per tree 5 shoots per tree
Aug 15		5 twigs per tree 5 shoots per tree
Sep 24	Harvest	5 twigs per tree 5 shoots per tree
Nov 14	Leaf fall	5 shoots per tree

All samples were frozen with dry ice from the time they were cut from the tree until shortly before they were placed in a forced draft oven for drying. Shoots and twigs were measured, cut into small segments, dried at 70 degrees C to a constant weight, ground to pass a 60 mesh sieve, and were then ball milled for 24 hours. Total sugars, starch and total nitrogen was determined on 1 gram portions of the samples. All carbohydrates are expressed as dextrose.

At harvest time yield records were made on each tree. Also, a 50-fruit sample was taken at random from each tree and fruit color ratings made by separating these 50 fruits into five color classes as follows: 0–20, 20–40, 40–60, 60–80, 80–100 per cent red surface color.

Results

The results are presented in Figs. 1 to 7. The data for nitrogen, starch and total sugars are presented both as per cent of dry weight and as milligrams per shoot or twig.

The average dry weight of shoots and of twigs for the 16 replications for each sampling date is shown in Fig. 1.[1] The different nitrogen treatments resulted in considerably different amounts of shoot or twig growth. The differences in shoot weights were associated with signifi-

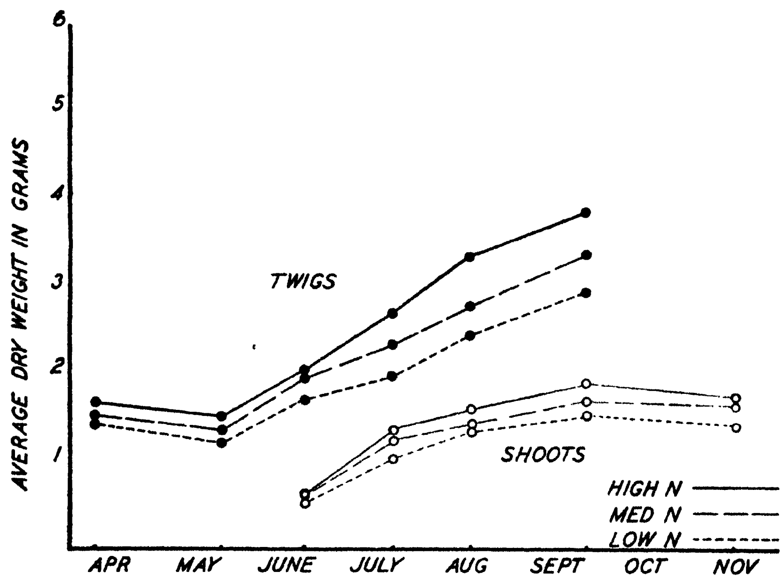

Fig. 1. Dry weight in grams per shoot and per twig, 1947 Shannon samples.

cant differences in shoot length. From April 8 to May 22 a slight decrease in dry weight of twigs was evident. As will be seen later this decrease was accounted for almost quantitatively by decreases in starch and sugars during the same period. From May 22 to the end of the season twigs made a steady increase in dry weight as a result of diameter increase.

The most rapid gain in dry weight of shoots was made prior to terminal bud formation (July 18) after which a steady but less marked gain was made up to the September 24 sampling. The slight decrease in dry weight of shoot samples from September 24 to November 14

[1]The term shoot is used to designate 1947 terminal growth and the term twig is used to designate 1946 growth.

may have been due to respirational losses coupled with translocation of carbohydrates to older portions of the tree.

That the differential nitrogen treatments were effective in establishing different levels of nitrogen in the trees is evident from a consideration of Figs. 2 and 3. In terms of percentage amounts (Fig. 2),

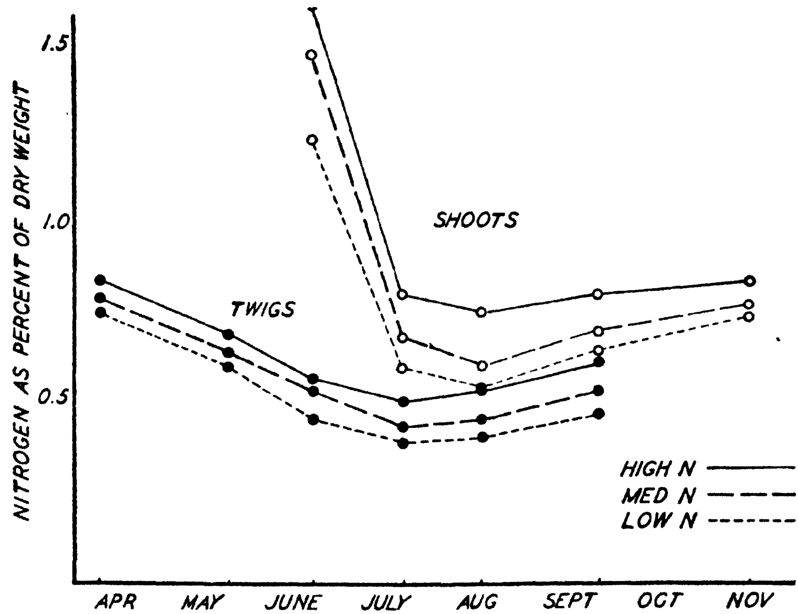

FIG. 2. Total nitrogen as per cent of dry weight in shoots and twigs, 1947 Shannon samples.

nitrogen decreased rapidly in shoots and twigs up to the time terminal buds were formed and then underwent a gradual rise throughout the remainder of the season. Shoots exhibited a higher level of nitrogen than twigs on a concentration basis. In terms of absolute amounts the reverse was true. On the absolute basis (Fig. 3) the differences in nitrogen per shoot or twig as a result of treatment were quite marked throughout the season but became more apparent as the season progressed. By September 24, twigs from high nitrogen trees contained approximately 70 per cent more nitrogen than corresponding low nitrogen twigs, and shoots from high nitrogen trees contained over 50 per cent more nitrogen than shoots from low nitrogen trees. The decrease in nitrogen content of twigs from April 8 to May 22 is attributed to utilization in growth by the young developing shoots and flowers. As contrasted with nitrogen on a per cent dry weight basis, absolute nitrogen per shoot or twig increased steadily from May 22 to harvest time, the most rapid increase in both shoots and twigs having taken place after July 18.

Unfortunately in 1947 and in the two previous years, weather during the pollination period determined the yields in this orchard. The

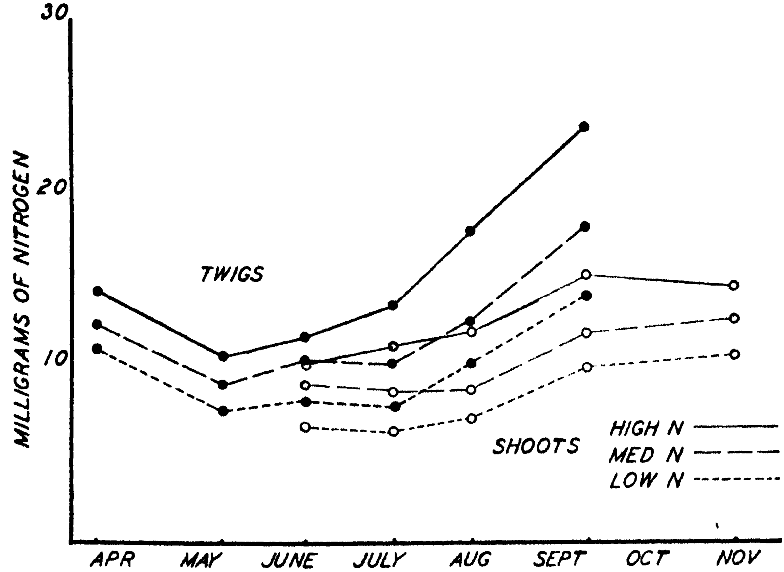

FIG. 3. Milligrams of total nitrogen per shoot and per twig, 1947 Shannon samples.

yields were about one-third of those attained by the high nitrogen trees in 1944, and there were no significant differences associated with nitrogen level. The fruit of the high nitrogen trees was significantly larger than that from the low nitrogen trees, however, and it was less well colored by a considerable margin.

The seasonal trends for starch in shoots and twigs expressed as per cent of dry weight (Fig. 4) are similar to curves for deciduous trees previously reported (2, 4, 7, 8). Shoots and twigs from the high nitrogen trees were lowest in starch and the low nitrogen twigs and shoots were highest in starch. The greatest differences between treatments occurred from the time terminal growth ceased to the end of the season.

On an absolute basis (Fig. 5) the shoots and twigs of the high nitrogen trees contained the largest amounts of starch and the shoots and twigs of the low nitrogen trees contained the least. Thus, although the concentration of starch was highest in the low nitrogen trees, the longer heavier high nitrogen twigs and shoots actually contained the most starch.

On a per cent dry weight basis there was no apparent difference in total sugars in either twigs or shoots as a result of differential nitrogen fertilization (Fig. 6). However, in terms of milligrams per shoot or twig (Fig. 7), it may be seen that the high nitrogen twigs and shoots contained the largest amounts of total sugars.

It should be emphasized that the quantitative determination of starch and sugars is laborious and time consuming and this fact makes

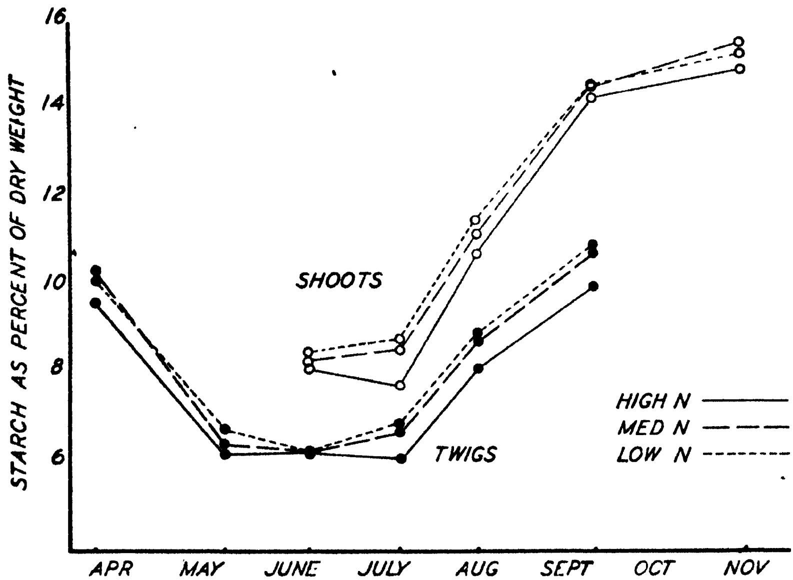

FIG. 4. Starch in shoots and twigs as per cent of dry weight, 1947 Shannon samples.

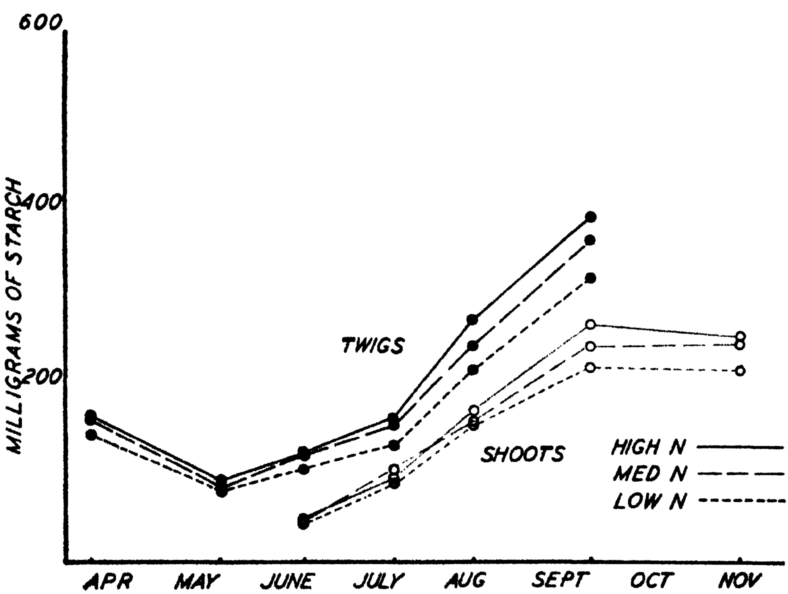

FIG. 5. Milligrams of starch per shoot and per twig, 1947 Shannon samples.

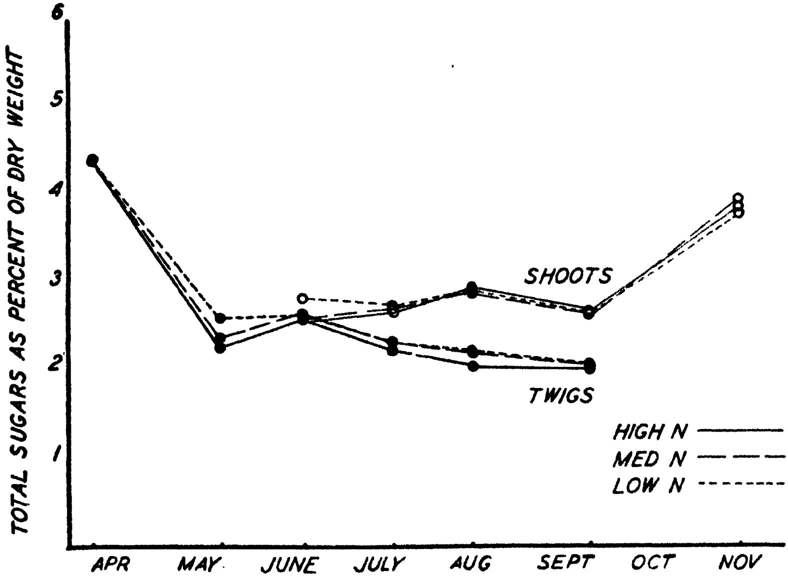

FIG. 6. Total sugars in shoots and twigs as per cent of dry weight, 1947 Shannon samples.

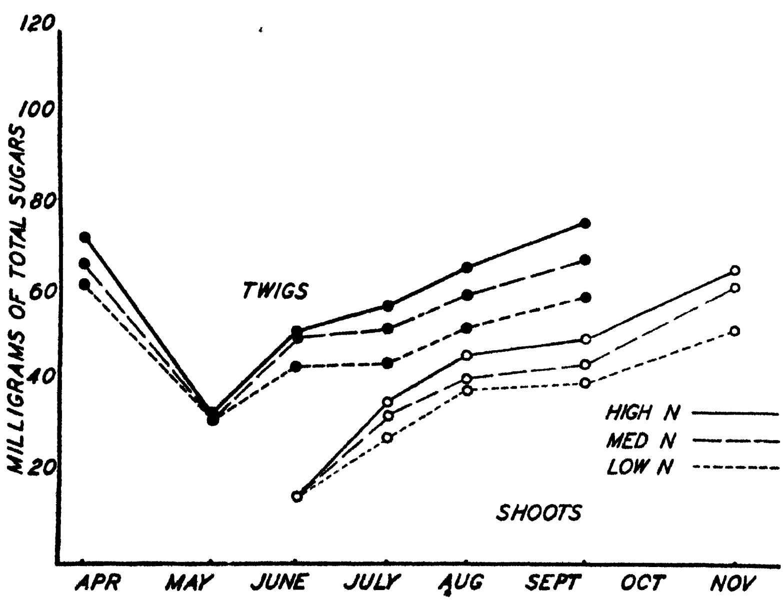

FIG. 7. Milligrams of total sugars per shoot and per twig, 1947 Shannon samples.

their use for diagnostic purposes of less value. With this in mind, the author had made some preliminary trials on the use of a microscopic technique for starch determination by sectioning shoot tissue and staining with IKI solution. In view of the limited results obtained in these preliminary trials, it appears that such a technique offers real promise for diagnostic work and warrants additional investigation.

Discussion and Conclusions

The levels of nitrogen attained in the trees used in this experiment varied from a condition of moderate deficiency in the low nitrogen trees to a moderate excess in the high nitrogen trees. These differences were reflected in vegetative growth, fruit color, and fruit weight. More to the point, they were reflected in shoot and twig carbohydrates. The differences in absolute amounts of carbohydrates attained the greatest extremes about harvest time. The significance of the relationships between nitrogen and carbohydrates may be shown by correlation coefficients. On September 24 a highly significant positive correlation, $r = .8296$, was obtained between milligrams of nitrogen and milligrams of starch in shoots. In twigs on the same date $r = .8017$. Between milligrams nitrogen and milligrams total sugars in shoots on September 24 there was also a strong positive correlation, $r = .9176$, while in twigs $r = .8895$. These relationships were obscured when percentage amounts were considered. This was especially true in the case of total sugars.

Starch exhibited the greatest variations as a result of treatment. This was evident only when the data were considered both in terms of concentration and absolute amounts since on a percentage basis starch was lowest in high nitrogen twigs and shoots while on the absolute basis it was highest in the high nitrogen twigs and shoots.

It is suggested that the quantitative determination of starch may serve as an additional tool in the diagnosis of the nitrogen status of the apple and, when used in conjunction with other measurements such as the determination of nitrogen, the various growth responses, and the determination of leaf chlorophyll will aid in the more efficient and profitable use of nitrogenous fertilizers.

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Further Experiences with the Chemical Thinning of Apples and Peaches[1]

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SINCE the results obtained in 1946 (4) indicated that the sodium salt of naphthaleneacetic acid (App-L-Set) offered some promise as a chemical thinner for several apple varieties in New York State when applied at calyx time and up to 12 days thereafter, a series of additional tests were carried out in the Hudson Valley and Western New York in 1947. This material, referred to as NaNAA in the text, was compared with the dinitro materials DN No. 1 (40 per cent dinitro-ortho-cyclohexylphenol), and Elgetol (20 per cent sodium dinitro cresylate) which have been used to a considerable extent as blossom thinning materials (3, 4, 5, 6). The reports of Kenworthy (2) and Flory and Moore (1) concerning the value of a spray mixture containing a specially prepared latex of polyethylene polysulfide (Goodrite p.e.p.s.) plus a compound formed by the reaction of zinc dimethyl dithiocarbamate (Zimate) with cyclohexylamine as an after bloom spray for thinning apples led to the further testing of this complex, also. Concentrations of all materials used are given in the tables.

The results of one experiment on the blossom thinning of Elberta peaches with the dinitro materials Elgetol, DN No. 1, and DN No. 289 (23 per cent of the triethanol amine salt of 2- secondary- butyl-4,6- dinitro phenol) are included. Goodrite p.e.p.s. plus Zimate with cyclohexylamine applied at shuck fall was the only after bloom treatment in this test.

The experiments were conducted on mature trees of uniform age, size, and bearing capacity. The number of trees, treatments, and times of application are indicated in the tables presented in the text.

At blossoming time, from 170 to more than 300 blossoming clusters or flowers on two representative unit branches of each apple or peach tree, respectively, were counted. Following completion of the June drop, the fruits remaining on the same branches were counted and the set records calculated. The fruit size data were obtained manually with sizing rings from a random sample of at least 3 bushels per tree in each treatment in the case of apples and from 1 bushel with peaches.

HUDSON VALLEY RESULTS

Apples:—During the period from April through June, 1947 the rainfall throughout the fruit districts of New York State was several inches throughout the fruit districts of New York State was several inches above average. In the Hudson Valley orchards where these tests were conducted, surface and internal soil drainage was excellent and water-logging of the soil was not a problem.

Uniform, heavily blooming Wealthy trees which were interplanted

[1]The Dow Chemical Company furnished a grant for carrying out this work and supplied all the materials except the Elgetol and Goodrite p.e.p.s. and Zimate with cyclohexylamine.

tree for tree with Delicious or McIntosh, were used for a test. The spur flower buds reached full bloom on the afternoon of May 16, and eight trees were sprayed with Elgetol and four with DN No. 1. The lateral and terminal flowering points on the past season's shoots reached full bloom stage 3 days later and a duplicate application of the dinitro materials were applied at half strength to four of the trees sprayed earlier with Elgetol and to all of those which had previously received DN No. 1. The remaining four trees which had been given an application of Elgetol on May 16 were sprayed with 10 ppm of NaNAA. An additional lot of heretofore untreated trees were given a drenching spray containing 15 ppm of NaNAA on May 19. Also, at calyx time one other group of four trees were sprayed with 20 ppm of NaNAA. The set, yield, and size records are given in Table I.

TABLE I—THE INFLUENCE OF SOME SPRAY MATERIALS APPLIED AT BLOOM TIME AND LATER ON THE SET, YIELD, AND SIZE OF WEALTHY APPLES (1947)

Treatment (Per 100 Gals Water)	No. Trees	Fruits Per 100 Blossoming Clusters	Average Yield (Bu)	Average Yield in Various Sizes (Bu)			Per Cent of Total Yield 2½ Inches +
				-2½ Inches	2½-3 Inches	3 Inches +	
Check	4	68.3	33.1	11.7	21.1	0.3	64.7
Elgetol 1 qt—May 16* 1 pt—May 19†	4	37.9	27.7	1.8	16.4	9.5	93.5
Elgetol 1 qt—May 16 NaNAA, 10ppm—May 19	4	27.8	31.2	0.9	16.6	13.7	97.1
DN No. 1 1 lb—May 16 ½ lb—May 19	4	32.1	27.0	1.3	16.1	9.6	95.2
NaNAA 15 ppm—May 19	4	58.6	—	—	—	—	—
NaNAA 20 ppm (calyx)—May 27	4	28.6	22.6	0.0	6.8	15.8	100.0

*May 16, 1947—First day of full bloom of the flowering spurs.
†May 19, 1947—First day of full bloom of the lateral and terminal flower buds on the past season's shoots.

The data show that all treatments except the application of 15 ppm of NaNAA on May 19 reduced the set considerably. No suitable explanation can be given for the failure of this treatment to reduce the set appreciably. All treatments tended to reduce the total yield. However, the volume of the crop reaching 2½ inches and larger was greater on all spray thinned trees than on the checks. It was very noticeable with this variety that the dinitro material, DN. No. 1 caused much less foliage injury than Elgetol, but that it was equally effective in reducing the set of fruit.

The Baldwin trees selected for treatment were located in a 10-acre block planted almost exclusively to this variety except for an occasional Cortland tree. On May 13 center flowers opened on the flowering spurs following the warm weather of May 11 and 12. May 13 was an excellent day for pollination and fertilization. For the next 5 days some cool, rainy weather occurred and full bloom of the flowering spurs was not reached until May 19. At this time the first dinitro applications were made as well as one application of 10 ppm of NaNAA.

When the lateral and terminal flowers on the past season's shoots reached full bloom on May 23, a second application of dinitro materials at half strength was made. At calyx time a spray containing 15 ppm of NaNAA per 100 gallons of water plus 1 pint of a light summer oil containing an emulsifier was applied to five trees. At this time five other trees were treated with a spray containing 20 ppm of NaNAA without oil. The results of this experiment are given in Table II.

TABLE II—THE INFLUENCE OF SOME SPRAY MATERIALS APPLIED AT BLOOM TIME AND LATER ON THE SET, YIELD, AND SIZE OF BALDWIN APPLES (1947)

Treatment (Per 100 Gals Water)	No. Trees	Fruits Per 100 Blossoming Clusters	Average Yield (Bu)	Pre-Harvest Drop (Per Cent of Total Yield)	Average Yield in Various Size (Bu)			Per Cent of Total Yield 2½ Inches +
					-2½ Inches	2½-3 Inches	3 Inches +	
Check	4	33.4	22.2	63.5	6.7	14.4	1.1	69.8
Elgetol 1 qt—May 19* 1 pt—May 23**	10	10.0	15.4	26.6	0.1	6.7	8.6	99.4
DN No. 1 1 lb—May 19 ½ lb—May 23	8	14.2	18.2	22.5	0.3	7.6	10.3	98.4
NaNAA 10 ppm—May 19	5	20.2	14.4	46.5	0.9	7.1	6.4	93.8
NaNAA 15 ppm—May 27+1 pt oil† (calyx)	5	17.1	15.9	39.0	0.4	5.5	10.0	97.5
NaNAA 20 ppm—May 27 (calyx)	5	19.0	18.4	50.0	0.4	9.6	8.4	97.8

*May 19, 1947—First day of full bloom of the flowering spurs.
**May 23, 1947—First day of full bloom of the lateral and terminal flower buds on the past season's shoots.
†Standard Oil of Indiana's L-6543, 98% emulsified with 2 per cent of B-1956.

From the fruit set records it can be seen that all treatments reduced the set considerably. In fact, the double applications of the dinitro materials reduced the set too much. This fact is reflected in the unusually large size of the fruit as well as in the reduction in total yield. The same statement can be made concerning the use of 15 ppm of NaNAA plus oil at calyx time. The oil apparently resulted in an increased penetration of NaNAA and reduced the set to a greater extent than the spray containing 20 ppm of NaNAA which was applied at the same time. This latter treatment did an unusually fine job of thinning. The fruits were evenly distributed, almost entirely as singles, throughout the bearing surface of the tree. The treatment seemed to result in the shedding of practically all of the fruits on the weak inside wood.

Another point of interest was the fact that the trees sprayed with the dinitro materials showed much less foliage injury from mites in August. Those trees which had been left as checks or had been chemically thinned with NaNAA sprays showed a marked degree of "bronzing" on the foliage, whereas those trees which received the dinitro materials at bloom time had a dark green foliage with little, if any, mite injury. Furthermore, the leaves injured by mites proved more subject to

damage from a series of mid-September frosts; so that, at harvest time, the foliage on check trees and those thinned with NaNAA was more sparse than the other trees in the test.

The October weather preceding and during Baldwin harvest was unseasonably warm and dry. The fruits matured rapidly during this period and the drop was heavy on the late varieties throughout the State. Although all the Baldwin trees in this test were sprayed several days before harvest with a drop preventative spray, those trees thinned with NaNAA or left as checks had a preharvest drop which was approximately twice as great as occurred from those trees thinned with the dinitro materials at blossom time. These data tend to confirm the general observation that the preharvest drop is apt to be most severe on trees which have foliage that has been seriously injured by mites or other causes and that drop preventive sprays may be ineffective.

The test on Delicious was conducted on two rows of trees which serve as cross-pollinizers for a block of Cortland. The trees reached full bloom on the afternoon of May 17. Since rain occurred on May 18, the applications of Elgetol, DN No. 1, and 7.5 ppm of NaNAA were delayed until the morning of May 19. At calyx time, one lot of five trees were sprayed with 10 ppm of NaNAA. The data obtained are presented in Table III.

TABLE III—THE INFLUENCE OF SOME SPRAY MATERIALS APPLIED AT BLOOM TIME AND LATER ON THE SET, YIELD, AND SIZE OF DELICIOUS APPLES (1947)

Treatment (Per 100 Gals Water)	No. Trees	Fruits Per 100 Blossoming Clusters	Average Yield (Bu)	Average Yield in Various Sizes (Bu)			Per Cent of Total Yield 2½ Inches +
				-2½ Inches	2½-3 Inches	3 Inches +	
Check	3	64.4	20.5	10.7	9.8	0.0	47.8
Elgetol—1 pt second day full bloom May 19	5	20.7	7.9	0.4	5.6	1.9	94.9
DN No 1—½ lb second day full bloom May 19	5	11.0	7.0	0.9	5.0	1.1	87.1
NaNAA—7.5 ppm second day full bloom May 19	5	19.0	11.6	1.2	7.8	2.6	89.7
NaNAA—10 ppm calyx May 27	5	16.5	12.1	0.9	8.2	3.0	92.6

Of the treatments used, the application of 10 ppm at calyx appeared to be most suitable. The dinitro materials undoubtedly reduced the set too greatly and resulted in a rather large reduction in total yield. However, in order to obtain Delicious of marketable size in New York State this variety, when well pollinated, must be heavily thinned, even at a considerable sacrifice in total yield. Delicious under 2½ inches in diameter are not generally considered of much value on the fresh fruit market. Hence, the marketable yield (apples 2½ inches and up) was actually greater where the set was reduced with the applications of NaNAA as compared to the checks where only 47.8 per cent of the crop was of marketable size. Also, the development of red color on the spray thinned trees was much superior to that which developed on the check. This was, also, the case with the Baldwins which were discussed earlier in the text.

Peaches:—The Elberta trees selected for testing were in a block where the grower has been successfully blossom thinning with Elgetol for the past 3 years. On May 6, 75 per cent of the flowers were open. Cool rainy weather existed for the next 2 days. The applications of Elgetol, DN No. 1 and DN No. 289 were made on the morning of May 9 when approximately 95 per cent of the flowers were open. Temperatures, as shown on a shielded maximum-minimum thermometer, dropped to 30 degrees F in this block on the early morning of May 9, a few hours before the trees were sprayed, and to the same reading on May 10, the morning after the sprays were applied. No frost injury to flower parts was detected. On May 27 a shuck spray containing 2 pounds of Goodrite p.e.p.s. plus ¼ pound of Zimate with cyclohexylamine per 100 gallons of water was applied on five trees.

The data in Table IV show that all the dinitro materials were effective in reducing the set and increasing the size of fruit as compared to the controls.

TABLE IV—THE INFLUENCE OF SOME SPRAY MATERIALS APPLIED AT FULL BLOOM AND LATER ON THE SET AND YIELD OF ELBERTA PEACHES

Treatment (Per 100 Gals Water)	No. Trees	Per Cent Set	Average Yield (Bu)	No. Fruits*	Prevailing Size (Inches)
Check	5	35.5	3.4	300.8	2⅛–2¼
DN No 289 ½ pt—May 9	11	10.4	2.2	181.4	2½–2⅝
DN No. 1 ½ lb—May 9	9	16.9	3.2	199.2	2⅜–2½
Elgetol 1 pt—May 9	12	13.5	3.0	205.2	2⅜–2½
P.E.P.S.—2 lbs Zimate—¼ lb Shuck spray—May 27	5	34.6	3.1	320.0	2⅛

*Determined from 1 bushel per tree in each treatment.

DN No. 289 appears to be rather potent blossom thinning material. It thinned to a greater extent than either DN No. 1 or Elgetol even though the spray contained only 2 ounces of toxicant per 100 gallons as compared to 3 to 3.5 ounces for the other dinitro materials. The influence of blossom thinning with the dinitro materials was reflected, also, in the development of shoots of greater length, diameter and number of flower buds than occurred on the check trees. The trees sprayed with Goodrite p.e.p.s. plus Zimate at shuck fall showed no reduction in fruit set and they were similar in all respects to the untreated trees.

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Apples:—The orchards where the tests were carried out in Western New York were adjacent to Lake Ontario in Wayne County. The area in general is level or only slightly rolling so that surface run-off is relatively slow. Also, the subsoil is heavy and compact in many of these orchards so that internal drainage was not nearly as good as in the lighter textured Hudson Valley orchards. During the period from April through June the rainfall in this area exceeded the normal for this period by approximately 5 inches. May was most outstanding in

this regard having 2.78 inches above average. The Delicious, Rome Beauty, and Baldwin trees which were included in the test, reported upon in Table V, reached full bloom during the last week in May.

TABLE V—THE INFLUENCE OF SOME SPRAY MATERIALS APPLIED AT FULL BLOOM AND LATER ON THE SET OF FOUR APPLE VARIETIES (1947)*

Treatment	No. Trees	No. Blossoming Clusters	No. Fruits	Fruits Per 100 Blossoming Clusters
		Baldwin		
Check	3	793	212	26.7
Elgetol—1 quart May 31, 1947	6	1,591	297	18.7
DN No. 1 May 31, 1947	7	2,320	359	15.5
Elgetol—1 quart May 31 NaNAA—20 ppm, Jun 5	4	1,187	64	5.4
NaNAA—20 ppm Jun 5	6	2,175	187	8.5
NaNAA—20 ppm +oil—1 pt Jun 5	6	1,760	70	4.0
		Rome Beauty		
Check	6	1,210	643	53.1
Elgetol—1 pt, May 28	6	1,131	48	4.2
DN No. 1—½ lb May 28	10	1,716	70	4.1
NaNAA—20 ppm, Jun 3	4	709	32	4.5
P.E.P.S.—2 lbs +Zimate—¼ lb Jun 3	4	756	318	42.1
		Delicious		
Check	5	1,098	360	32.8
NaNAA—10 ppm, Jun 4	5	1,090	14	1.3
NaNAA—10 ppm +oil—1 pt Jun 4	5	1,224	5	0.4

*The applications of dinitro materials were applied at approxinately the second day of full bloom. All the other materials were applied at calyx time.

The pollination weather during the blossoming period was considered as fair. The soil, however, was in a "water-logged" condition with surface water standing in some areas. Considering these factors, blossom applications of dinitro materials on Rome Beauty and Baldwin were delayed approximately 1 day and were applied on the second day of full bloom rather than on the first day of full bloom which has been the usual practice with these varieties. Only calyx applications of NaNAA were made on Delicious with the idea of allowing all cross-pollination possible to take place.

When calyx applications were made on June 3 to 5, the soils were still water-logged and remained so for the next 10 days to 2 weeks. On June 10 and 11, temperatures of 94 and 93 degrees F were reached.

The set records obtained from the Baldwin trees show that an application of NaNAA at 20 ppm at calyx thinned to a much greater extent in this orchard than the dinitro materials applied at blossom time. This is contrary to the results obtained in the Hudson Valley (Table II) on this variety. Also, it appears that the addition of oil to sprays containing NaNAA increases its potency as a post-bloom thinning material. The reduction in set caused by the dinitro materials appeared to be suitable for the production of a moderate crop. The set on the checks was relatively light considering the amount of bloom and vigor of the trees. With the variety Rome Beauty, all treatments markedly overthinned except Goodrite p.e.p.s. plus Zimate which had little, if any, effect on set. The calyx applications of NaNAA on Delicious caused almost complete removal of the crop.

Discussion

Certain of the treatments used for chemical thinning reduced the crop more in the Western New York tests than in the Hudson Valley. This was especially true where NaNAA was used for thinning Delicious and Baldwin. Also, this material failed to thin Rome Beauty in a Western New York orchard in 1946 (4) but overthinned the crop in the same block in 1947.

Water-logging of the soil was a serious problem in Western New York orchards in 1947. Natural abscission of young fruits under these conditions may be much greater than occurs when good internal soil drainage exists. Baldwin trees in water-logged areas in 1947 shed fruit as large as an inch or more in diameter which contained as many as five and six seeds. This indicates that poor soil aeration may increase the June drop. This increase in drop is probably a reflection of poor soil aeration on the growth of root and the absorption of water and nutrients. As previously stated, on June 10 and 11 extremely hot weather occurred which may have resulted in a temporary water deficiency in the tree and increased the tendency of the young fruits to absciss. A temporary shortage of nitrogen due to decreased nitrogen absorption may have been a factor, also. A third possibility may be the appearance of some toxic materials in the soil during this period of anaerobic conditions. In any event, it seems that a given concentration of NaNAA might cause the shedding of more young fruits when the soil is water-logged than when conditions are favorable for root activity.

Aside from this fact, the use of NaNAA appears to be a promising material as an after bloom chemical thinning material. However, before it can be considered superior to the dinitro materials it must be tested over a period of years to determine its uniformity of performance and whether or not definitely alternating varieties such as Wealthy will bear annually following such treatments.

The complex containing Goodrite p.e.p.s. plus Zimate with cyclohexylamine failed to reduce the set of all apple and peach varieties on which it was used as an after bloom spray.

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A System Aiding Diagnosis of Nutrient Deficiencies in Fruit Trees (A Preliminary Report)

By T. A. MERRILL, *Washington Agricultural Experiment Station, Pullman, Wash.*

NUTRIENT deficiencies of one type or another are common orchard ills which prevail throughout most of the fruit sections of the United States. These troubles are not always easy to diagnose and the common control methods of applying mineral elements to the soil surface and then waiting for results is time-consuming and often unsatisfactory. Usually one must wait for a year or more after applying them before results become evident.

Following the system of pressure injection as described by Southwick (1), the writer developed the pressure tank shown in Fig. 1 for direct injection of nutrients into the phloem tissue. The pressure container was made from a standard hot water tank of 300 pounds pressure specifications, cut down to 5-gallon capacity and rewelded. The liquid was placed in the tank through an opening in the top and likewise a valve stem, from an old inner tube, for the air pressure. A 200-pound air gauge indicated the pressure, and a pipe extending from the bottom of the container through the top of the tank provided the outlet for the solution. The upper end of this pipe was fitted with a

FIG. 1. Pressure tank with connections. Showing method of applying nutrients by this means.

tee and four welded valve couplings. Attached to each of the valve couplings was a 10-foot piece of ⅜-inch inside diameter saran tubing. At the end of each piece of tubing a standard brass compression coupling was used so that the "needle", after a 5/16-inch hole was bored in the tree could be inserted without injury to the bark. The saran tubing was then securely tightened to the needle making an air-tight connection.

The shut-offs at the tee were steam-type valves which prevented any air leakage. All couplings, including the tee were of brass to prevent corrosion. The "needles" had a tapered lag-screw-type thread on one end and a pipe thread on the other. Air pressure was obtained from a small portable air compressor operated by a 1-horse-power gasoline engine.

Injections were made with this equipment by the writer in 1946 and 1947 in apple, pear, sweet and sour cherry, peach and apricot trees. Using complete nutrient solutions made up according to Miller (2), solutions from normal concentrations to 10 times normal were used in these preliminary trials. Concentrations to 5 normal strength were taken up readily by all trees injected, but concentrations of 10 normal strength were unsatisfactory as it was generally impossible to get solutions of this concentration into the tree. Injections made at 100 pounds pressure required 15 to 40 minutes per gallon, the actual time required depending on the type of tree. To date, no injury has been observed from either of these concentrations or from the pressure used when injecting the solution into the trees.

FIG. 2. Apple tree showing zinc deficiency. This tree was treated by injection method spring of 1947. Photo taken same day as treatment was made.

Fig. 2 shows an apple tree affected with zinc deficiency. This tree received 1 gallon of 5 normal ZN solution in the spring of 1947. The bare area on the 1946 growth produced no leaves during the 1947 season. The 1947 growth appears to be normal.

Treating single branches on trees is an effective method of determining possible causes of nutrient deficiencies. To date, treating one branch apparently has shown no effect on the remainder of the tree. Further observation will be made to determine this more definitely.

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Growth and Blossoming of Some Apples[1]

By R. H. Roberts, *University of Wisconsin, Madison, Wis.*

When making a study of the growth and pollination conditions affecting the setting of Delicious, it was noted that the amount of blossoming of individual branches varied directly with the amount of terminal growth in the previous year; that is, in the year when the blossom buds were formed (1, Fig. 2). On trees which were fruiting, branches making little terminal growth had a high percentage of blossom buds, those with 8 to 10 inches of terminal growth had medium percentages, and branches with terminals longer than 20 inches did not, as a rule, form blossom buds. That is, branches of Delicious making 20 to 24 inches or more of growth are "over-vegetative" until such time as they make less growth in length. In the previous surveys, it was also recorded, as occurs regularly, that the percentage set of fruit was inverse to the amount of blossoming. Large apples were borne on branches with a good terminal growth and small apples on branches with a short terminal growth. The vigorous branches with low percentages of growing points blossoming were regular bearing. Thus, the best commercial crop resulted on individual branches when 30 to 50 per cent of the growing points blossomed.

In 1947 data were collected to determine the relation of the length of terminal growth to blossom bud formation on the individual branches of eight commercial varieties. Except for the Golden Delicious trees, the orchards used in the current studies were 30 to 35 years old and in good states of vigor. The regularly bearing Golden Delicious were 8 to 10 years of age and the biennial trees 18 to 20 years old. The results of the length measurements and counts of 79,750 growing points are shown by Figs. 1 and 2. Several interesting as well as economically important facts are apparent:

1. Winesap does not form excessive percentages of blossom buds in Wisconsin and, as a consequence, has alternating sets of growing points to provide annual blossoming.
2. Fig. 1 shows why most growers of McIntosh are successful producers of this variety. Its branches fruit well and regularly when making only 5 to 10 inches of terminal growth. This is easy to secure.
3. The strongly biennial varieties Duchess and Wealthy have excessive percentages of blossom buds on even vigorous branches with 18 to 20 inches of terminal growth. Enough growth to give only 20 to 30 per cent of blossom bud formation cannot be attained readily, making it impracticable to secure annual bearing through stimulating growth.
4. Varieties as Delicious, Jonathan and Northwestern Greening can be kept regularly bearing if a considerable percentage of the terminal growths are as much as 15 to 20 inches long.
5. In Wisconsin it is difficult to secure enough growth on Golden Delicious to avoid excessive blossoming. This fact and its habit of heavy setting makes annual bearing hard to maintain.

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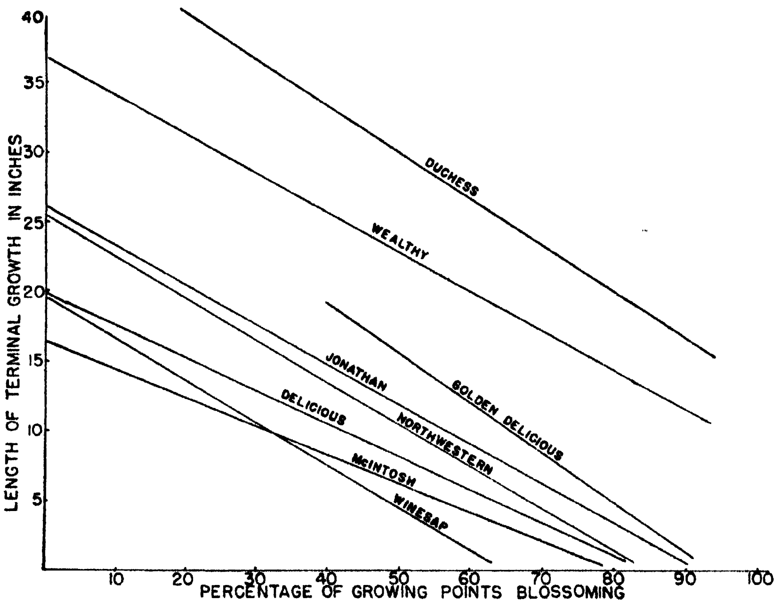

FIG. 1. Showing the relation of length of terminal growth of a branch and the percentage of blossom bud formation of several apple varieties.

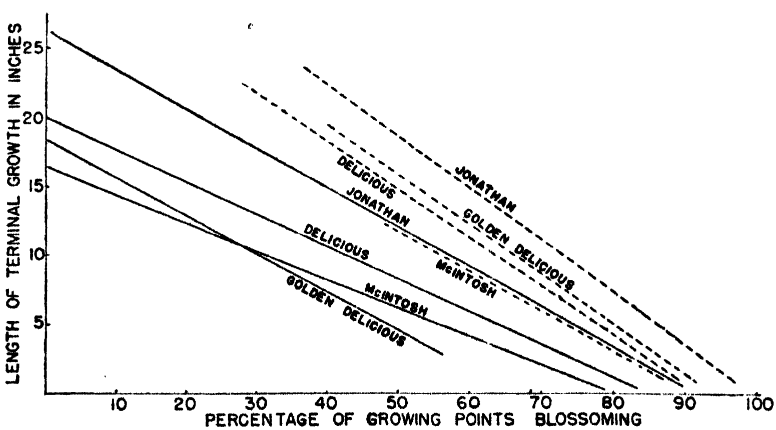

FIG. 2. Showing the growth and blossom bud formation of annually bearing (solid lines) and biennially bearing (broken lines) trees of four apple varieties.

It is recognized, of course, that the relation of terminal growth and blossom bud formation is affected by various environmental conditions. For example, abundant blossom bud formation was seen on Delicious growths as much as 4 feet long in a small area with superior

moisture conditions in Southern Tennessee (Fig. 3). Blossom bud formation may be reduced by defoliation from scab or spray injury if this occurs early enough in the growing season. The opposite effect of increased differentiation results from the killing of the blossoms by spring frost.

FIG. 3. Under unusually favorable growing conditions abundant blossom bud formation may occur on long terminals of Delicious.

The effect of having pruned off the branches with little terminal growth through previous years, upon the relation of growth and blossom bud formation, is shown by Fig. 2. The percentage of blossoms on trees which are full of branches with little growth is 20 to 30 higher for branches with a given terminal growth (broken lines) than when the trees have received a "detailed" pruning which removed most of the branches making only a few inches of terminal growth (solid lines). This type of pruning helps to keep the trees bearing regularly. It is also a means of removing or avoiding many or most of the small apples which would otherwise need to be thinned off.

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Notes on Pollination with Special Reference to Delicious and Winesap[1]

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THIS report is primarily a further study in connection with why Delicious sometimes sets poorly. Earlier reports have pointed out that the blossom structure of Delicious is such that a honey bee can extract the nectar without pollinating the blossoms in as much as 80 per cent of its visits (2) and that Delicious sets well if given an abundant nearby source of compatible pollen (3). Similar evidence resulted from a second survey in 10 midwestern states in 1947.

While making the survey on the setting of Delicious in 1946, it was

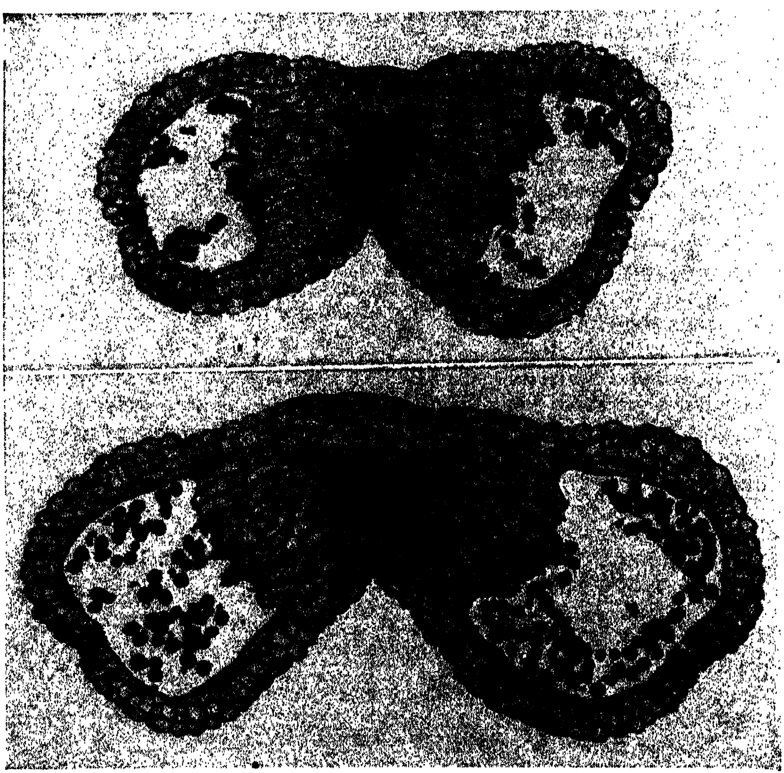

FIG. 1. Cross-sections of anthers of Delicious (below) and Winesap (above). Note the sparse production of pollen by the smaller Winesap anthers.

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[2]Appreciation is expressed for the courteous assistance of Prof. W. W. McGill and Dr. W. D. Armstrong of the Kentucky Stations and Dr. R. C. McMunn of the University of Illinois.

noted that trees standing beside Winesap bore a better crop than those in the second and more distant rows. This suggested that Winesap did function, to some extent, as a pollinizer for Delicious. This situation was given some attention in 1947. Pollen was collected in the Kentucky and Southern Illinois orchards where it had appeared that Winesap had served as a pollen source for Delicious.[2] Winesap produces little pollen (Fig. 1). This is difficult to collect and does not transfer readily when hand pollinating. An effective method of securing fruit set on other varieties with Winesap pollen is to use the tip of

FIG. 2. Germination of Wealthy (below) and Winesap (above) pollen.

a finger to which the pollen adheres readily. Professor J. R. Cooper of the Arkansas Experiment Station reports that Winesap will fertilize and set Delicious satisfactorily with the following procedure: dry some balloon-stage blossoms. To pollinate, break off the dried petals and apply the dry anthers to the Delicious stigmas.

In preliminary tests, Winesap pollen germinated as well as that of Duchess, Early Harvest, Golden Delicious and Grimes Golden (about 60 per cent) but not quite as well as Delicious (73 per cent) Fig. 2. Further trials made in triplicate gave the average results shown in Table I. The media used was 10 per cent sucrose with 2 per cent agar.

TABLE I—EFFECT OF TEMPERATURE UPON PERCENTAGE POLLEN GERMINATION (1947, 24 HOURS AFTER SEEDING ON AGAR)

Variety	Degrees C							
	8	12	16	20	24	28	32	36
McIntosh	8.0	15.6	32.2	40.4	36.1	32.1	19.3	Tubes Burst
Wealthy	0.0	8.3	32.7	41.2	54.7	50.0	39.1	
Winesap	0.0	6.7	11.8	25.4	27.4	19.2	16.9	——

An additional comparison of the germination of Winesap and other varieties of pollen is shown in Table II.

Good sets of fruit were secured on several varieties in Wisconsin by using Winesap pollen (Table III). Pollen was transferred from the storage vial to the stigmas with the tip of the finger.

TABLE II—PERCENTAGE GERMINATION OF POLLEN FROM BLOSSOMS IN DIFFERENT STAGES OF DEVELOPMENT, 4 TO 5 HOURS AFTER SEEDING

Variety	Days After Collecting	Blossom Stage*						
		I	II	III	IV	V	VI	VII
Duchess	2	77.0	66.0	64.5	63.1	61.6	52.0	50.0
	18	56.8	37.8	——	——	——	10.0	5.1
Golden Delicious	2	83.3	72.0	69.5	63.7	52.9	35.2	17.9
McIntosh	2	58.8	54.1	41.7	22.6	17.1	16.1	9.6
	15	44.6	40.4	26.5	11.4	6.0	5.5	6.0
N. W. Greening	3	55.2	49.6	47.2	42.9	41.9	40.8	8.3
Wealthy	2	79.4	75.4	59.8	47.1	27.8	19.0	5.2
	15	61.3	51.2	48.2	28.2	9.7	——	4.2
Winesap	1	35.6	28.8	27.6	25.7	23.1	22.9	Pollen did not shed
	8†	34.9	30.9	28.1	27.8	22.3	18.9	
	1†	60.9	55.5	55.5	48.0	41.7	27.7	
	8	49.0	43.5	40.3	36.2	27.3	31.6	

*I. Petals open; II. petals spreading; III. balloon; IV. early balloon; V. late closed cluster (before the blossoms separate in the cluster); VI. closed cluster; VII. early closed cluster; see Fig. 3.
†24 hours after seeding.

One reason for the poor setting of Delicious in the Middle West (2, 3) is that every blossom is not a potential apple. Delicious has a relatively low percentage set even when the flower cluster is thinned to a single pollinated blossom. For example, the percentage sets in 1947 were: Wealthy, 100; McIntosh, 65; and Delicious, 53. A crop of apples cannot be set in this territory by pollinating the central blossom in every fourth or fifth cluster, as is a commercial practice in the Wenatchee Valley, Washington, (4). Neither experimental nor com-

mercial trials of this procedure have proven successful in previous years. This year a good crop of apples resulted from trials in six orchards when three blossoms were pollinated in every third to fourth cluster. The average number of spurs in each 100 with blossoms having apples after the first drop was 61.3 when hand pollinated as compared to 6.0 without hand pollination. The trials were located in orchards with known inadequate pollination conditions.

When hand pollinating, there was an advantage in using the center blossom of the cluster, Table IV. The average increase in set of the center blossom over lateral blossoms of the cluster was 17.3 per cent.

TABLE III—PERCENTAGE SET OF FRUIT WITH WINESAP AND OTHER POLLENS

Variety	Pollen Variety											
	Winesap		Golden Delicious		Jonathan		McIntosh		Rome Beauty		Wealthy	
	I*	II†	I	II	I	II	I	II	I	II	I	II
Delicious	29.4	11.8	42.2	21.7	47.6	28.6	59.9	39.8	69.2	27.5	11.1	11.1
Golden Delicious	78.1	26.8	—	—	—	—	68.0	24.5	84.4	34.4	—	—
McIntosh	15.9	9.1	—	—	—	—	—	—	—	—	74.4	18.9
N. W. Greening	74.2	15.5	40.7	27.1	53.5	12.7		—	61.1	15.3	25.6	—
R. I. Greening	4.5	0.0	4.3	0.9	—	—	—	—	54.0	6.7	—	—
Stayman Winesap	0.0	—	16.7	—	14.9	—	59.3	7.7	—	—	—	—
Tolman Sweet	54.2	16.7	—	—	—	—	—	—	44.4	15.6	—	—
Wealthy	60.0	38.8	86.7	41.6	96.1	42.3	100.0	36.6	80.7	25.2	—	—
York Imperial	4.0	1.3	71.4	8.6	74.6	8.9	—	—	19.6	0.0	12.5	—

*Percentage sets after the first drop.
†After the June drop.

TABLE IV—SET OF CENTRAL AND LATERAL BLOSSOMS (PERCENTAGE OF POLLINATED SPURS WITH FRUITS AFTER THE JUNE DROP, MIXTURE OF POLLEN FROM SEVERAL VARIETIES WAS USED)

Treatment	Delicious (1946)	McIntosh			Golden Delicious (1947)	Average
		1946	1947			
			A*	B*		
1 Center	58.8	93.0	70.8	92.6	77.3	78.1
C+1 Lateral	72.7	85.0	33.3	76.0	88.0	71.0
C+2 Laterals	78.0	78.3	40.8	76.0	45.7	63.8
C+3 Laterals	84.2	100.0	24.0	52.0	82.4	68.5
C+4 Laterals	66.7	86.4	0.0	87.3	44.0	56.9
1 Lateral	48.0	68.3	44.0	73.7	65.1	59.8
2 Laterals	40.0	58.3	12.0	44.0	56.0	42.1
3 Laterals	61.6	80.0	37.4	62.5	14.3	51.2
4 Laterals	68.4	66.7	22.8	64.0	75.0	59.4

*Two orchards.

As a check on the limit of time in which hand pollinating can be done successfully if the weather prevented natural pollination, three varieties were pollinated at daily intervals after the balloon stage. Good sets of fruit were secured with Wealthy when pollinated 3 days after full blossom (27.0 per cent after the June drop) and 2 days in the case of Northwestern Greening (20.6 per cent) and Tolman Sweet (27.4 per cent).

The effect of pollinating McIntosh at different stages of blossom development is shown by Table V.

TABLE V—FRUIT DEVELOPMENT FROM POLLINATING YOUNG BLOSSOMS OF MCINTOSH (1946)

Blossom Stage*	Per Cent Set, After June Drop	Fruit Weight (Grams)	Seed Numbers
I	76.5	78.3	8.3
II	75.0	77.1	7.9
III	79.6	70.6	6.7
IV	45.8	72.2	5.5
V	37.0	58.6	3.9
VI	13.9	48.2	3.6

*See footnote, Table II and Fig. 3.

It is apparent from these data that care need not be taken to avoid early balloon stages (Stage IV) when making pollination tests.

The percentage of set of fruits of McIntosh in 1946 was not reduced by pollinating less than the five stigmas. Pollinating only one stigma gave as good a set of fruits as when more were pollinated. However, the apples were smaller and had fewer seeds when only one or two stigmas were pollinated.

Pollen from blossoms in as early a stage as the closed cluster (Fig. 3, Stage VI) set Wealthy and McIntosh as well as did pollen from blossoms in a late balloon stage.

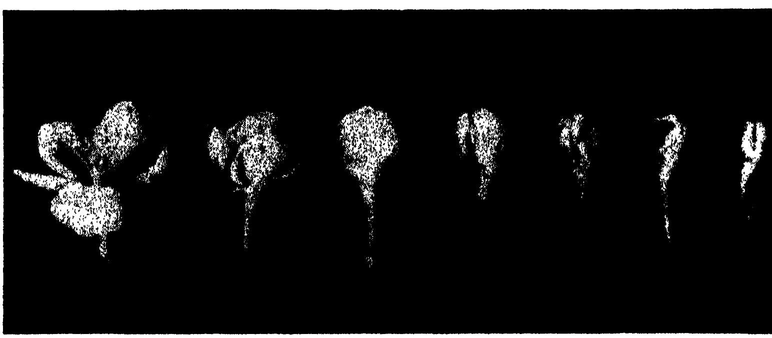

FIG. 3. Blossom stages referred to in Tables II and V. Left to right, Stages I to VII.

Removal of the sepals when emasculating may greatly affect the set, particularly some seasons and with some varieties. This year the following percentage sets were secured with petals only removed and with the calyx off: Delicious, 28.2 and 5.3; Northwestern Greening, 43.1 and 2.0; Rhode Island Greening, 54.0 and 0.0; Wealthy, 80.7 and 58.6; and York Imperial, 74.6 and 8.0. These counts were made after the first drop.

Under the very poor pollinating conditions at Madison this year, some varieties set much more poorly on the north side of the trees than on the south side. A particular case is that of McIntosh with 6.8 fruits on the north side and 34.3 fruits on the south side per 100 spurs, after the first drop. The counts on Duchess were 144 and 312, and

on Cortland 227 and 318. The earlier blossoming variety, Fameuse (Snow) had more favorable pollination weather and showed no significant difference in the set on the two sides of the tree, the numbers being 128 and 136.

It is obvious that data taken at harvest time may not indicate the relative value of a variety of pollen in setting fruits. This is because of the characteristic heavy drop after a good early set. A poor early set may even give a better final crop (about 25 fruits on a hundred total spurs) than a heavy early set. Also, to secure an accurate record of the value of a pollen, the set should be calculated on a basis of the amount of blossom on the branches being pollinated (1). For example, a 30 per cent set on a branch with 80 per cent of the spurs blossoming is a better average set than a 60 per cent set if the branch has only 30 per cent of the spurs blossoming (3, Fig. 2).

A truer measure of the effect of a pollen in setting fruits on a variety can be obtained by heavily thinning the blossoms in the clusters at the time of pollinating. This eliminates competition and reduces the "nutritional" second and June drops. In 1947, Wealthy set and held to maturity 100 per cent of the blossoms pollinated with a mixture of pollen when only one blossom on every four spurs was pollinated. When three blossoms on every other spur were pollinated, the initial set was 91.1 per cent and 25.2 per cent matured into fruits. When four blossoms were pollinated on every spur, the sets were 94.0 after the first drop and 23.4 after the June drop. When three-quarters of the pollinated blossoms drop from nutritional causes, the value of a pollen cannot be determined.

The data presented here were not corrected to eliminate the factor of the effect of amount of blossoming upon setting. The precaution was taken, however, of pollinating the flowers on branches with comparable amounts of blossom. Poor sets of fruit were secured with the following combinations this year: Delicious on Tompkin's King and Rome Beauty; Duchess on Delicious; Golden Delicious on Tompkin's King, Rhode Island Greening, Stayman Winesap, and Virginia Crab; Grimes Golden on Stayman Winesap and Turley; (Tompkin's King pollen set Virginia); McIntosh on Tompkin's King (but it set Stayman Winesap); Northwestern Greening on Rhode Island Greening; Rhode Island Greening on Delicious (but it set McIntosh and Virginia Crab); Northern Spy on Rhode Island Greening; Wealthy on Delicious and Tompkin's King. Many, but not all, of these failures involve triploids. Turley set Virginia Crab.

Particularly good sets were secured with Cortland on Delicious; Jonathan on Grimes Golden; Rome Beauty on Delicious; and Winesap on Wealthy.

SUMMARY

Properly handled Winesap pollen germinated well and set fruits on several varieties this year.

Delicious set good crops when three blossoms instead of one blossom of every fourth cluster were hand pollinated.

Pollen germinated well through a wide temperature range. That

from McIntosh germinated better than Wealthy and Winesap at cooler temperatures.

Pollen from early unopened blossoms germinated well and set fruit well.

The central blossom of Delicious, Golden Delicious and McIntosh clusters set 15 to 20 per cent better than the lateral blossoms.

Pollinating 2 to 3 days after full blossom gave good sets of Northwestern Greening, Tolman Sweet and Wealthy in the cool season of 1947.

Good sets of McIntosh resulted from pollinating blossoms in the very early balloon stage.

Fruits of good size and seed number resulted from pollinating only two or three stigmas.

Blossom thinning increased the initial set.

The second and June drops obscure pollen influence, especially as they are heavier when the initial set (from good pollen) is higher.

Sepal removal when pollinating generally reduces or prevents setting.

Under very poor pollinating conditions apples set poorly on the north sides of the trees in 1947.

The amount of blossom on pollinated branches should be considered when evaluating pollen effects.

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The Occurrence of Spontaneous Triploids and Tetraploids in Apples[1]

By JOHN EINSET, *New York State Agricultural Experiment Station, Geneva, N. Y.*

A FIRST report on the spontaneous occurrence of polyploid apples was made by the author in 1945 (1). Since that time more data have been obtained and this paper is a progress report and a summary of the polyploid apple material now available at the Geneva Station.

TRIPLOIDS FROM DIPLOID SEED PARENTS

The frequency of occurrence of triploid apple seedlings in progenies of diploid parents is shown in Table I. About 60 per cent of the seedlings came from controlled crosses and the other 40 per cent grew from open-pollinated seed. Root tip counts in a total of 6002 seedlings revealed 19 triploids; triploids occurred with a frequency of approximately 1 in 315 in this population. The frequency of occurrence of triploids in progenies of different seed parents indicates strongly that certain varieties have a greater tendency to produce triploid seedlings than other varieties. This means that certain varieties tend to produce more unreduced eggs than others because these triploids are presumably originated through the functioning of an unreduced egg fertilized by a normal pollen grain.

TETRAPLOIDS FROM DIPLOID SEED PARENTS

In the same population of 6002 seedlings of diploid parents reported in Table I, six plants were found that were wholly or in part tetraploid (Table II). Several additional roots were taken of plants which on initial determination were found to be polyploid, in order to verify the chromosome counts. The first three seedlings in the table appear to be wholly tetraploid from root-tip counts. The last three seedlings

TABLE I—THE OCCURRENCE OF TRIPLOID APPLE SEEDLINGS IN PROGENIES OF DIPPLOID PARENTS

Seed Parent	Triploids (51 Chromosomes)	N*	Frequency of Occurrence
Bedford	0	65	—
Cortland	1	434	1 in 434
Delicious	2	134	67
Golden Delicious	1	345	345
Grimes Golden	0	80	—
Jonathan	0	37	—
Macoun	5	674	135
McIntosh	1	636	636
Northern Spy	9	2,789	310
Ogden	0	287	—
Saratoga	0	309	—
Wagener	0	32	—
Yellow Newtown	0	180	—
Total	19	6,002	1 in 315

*N equals the number of individuals in the population.

[1]Journal Paper No. 746 New York State Agricultural Experiment Station, Geneva, N. Y., January 12, 1948.

TABLE II—TETRAPLOID SEEDLINGS OF DIPLOID PARENTS

Cross*	Remarks
1. Macoun ×Jonathan	4 roots wholly $4n$
2. Ogden ×T. de Croncels	3 roots $4n$
3. Golden Delicious ×Bedford	6 roots $4n$
4. Red Spy ×Station No. 1546	1 root wholly $4n$ 3 roots $2n$
5. Red Spy ×Golden Delicious	2 roots $4n$ 4 roots $2n$
6. Red Spy ×Golden Delicious	2 roots $4n$ 1 root $2n$

*The seed parent stands first in each case.

had some roots that were wholly $4n$ with 68 chromosomes and other roots that were diploid. Investigation of the above-ground parts may reveal a sectorial condition here also.

TETRAPLOIDS FROM TRIPLOID SEED PARENTS

Seedlings were grown, mostly from open pollinated seed, of a number of the more important triploid varieties of apples and chromosome counts were made in root tips. A total of 94 tetraploids were found among 3920 seedlings examined (Table III). The seedlings investigated were a highly selected group with regard to vigor because most seedlings of triploid seed parents are aneuploids and have very poor vigor (1). Therefore, the frequencies in Table III have no par-

TABLE III—THE OCCURRENCE OF TETRAPLOID APPLE SEEDLINGS IN PROGENIES OF DIPLOID PARENTS

Seed Parent	Tetraploids (68 Chromosomes)	N*	Frequency of Occurrence
Baldwin	10	585	1 in 58
Fallawater	12	759	63
Graue Herbst Reinette	11	160	16
Gravenstein	39	1,222	31
Ribston	4	240	60
Stark	16	640	40
Tompkins King	2	314	157
Total	94	3,920	1 in 42

*N equals the number of individuals in the population.

ticular significance except that they do give some indication of the number of seedlings that should be potted in order to find a given number of tetraploids. Certain parents, notably Graue Herbst Reinette and Gravenstein, produced a high number of spontaneous tetraploids when compared with some of the other varieties and did so all 3 years that seed collections were made.

PERICLINAL CHIMERAS — PARTIAL TETRAPLOID SPORTS

A number of large-fruited sports of apple varieties have been investigated and reported to be periclinal chimeras (2, 3, 4). These sports are in part diploid and in part tetraploid and are of three different types. The members of the first type, a "Large" Wealthy (Stevenson), "Giant" Wealthy (Loop) and the Ontario sport, are wholly tetraploid

except for the epidermal layer of cells which is diploid. These sports breed like tetraploid apples and when crossed with diploids produce triploid seedlings. Such crosses were made this past season for the first time and a number of seeds were obtained.

The chimeras of the second type include "Giant" Spy (Loop) and the Jonathan sport (Welday). The epidermal as well as subepidermal layers of cells in the stem apices are diploid in these sports. The deeper cell layers are all tetraploid. The sixth periclinal chimera is a "Giant" Rome (Loop) and represents a third type. This has three layers of diploid cells covering the tetraploid interior in the shoot apex. Since sporogenous tissues are derived from the second layer of the apex, the forms representing the last two types behave like diploids when used in breeding and therefore are not of as much interest in the breeding program as are sports of type 1.

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An Unprofitable Strain of the Grimes Apple

By J. A. McClintock, *Purdue University Agricultural Experiment Station, Lafayette, Ind.*

For some time horticulturists have recognized the presence of strains within varieties of apples. In cases where strains have commercially desirable characteristics, such as the red-fruited bud sports, they have attracted much favorable attention. Undesirable strains of apples have received minor consideration to date. Definite evidence of strain differences in McIntosh has been presented by Tukey and Brase (1), and by McClintock (2).

In stock-scion studies, the writer has observed several strains of Grimes the fruits of which vary from the normal in size, shape or season of maturity. In each case these variations were so obviously undesirable that no attempt was made to propagate them.

The unprofitable strain which is the subject of this report had been propagated commercially, and first came to the writer's attention in 1934, when trees for a new variety plot were obtained from an Indiana nursery. The purchase order had specified that the Grimes trees should be on Virginia Crab understocks, to insure against Phytophthora collar rot infection.

Previous reports by Cullinan (3), McClintock (4), and Maney (5) of Grimes on Virginia Crab had indicated that this combination produced vigorous tree growth; therefore the writer became suspicious when he observed the slow growth made by the 16 Grimes trees set in this new variety block. In comparison with trees in adjoining rows of Rome and Stayman, set at the same time, these Grimes trees were dwarfish in growth. As the dwarfing became conspicuous in the succeeding years, the writer seriously doubted the understock being Virginia Crab. In 1943 sucker growths typical of French crab seedlings developed about the base of one of the trees. This confirmed the writer's suspicion that the Grimes were not on Virginia Crab understocks.

When the Grimes trees came into bearing in 1940 they set heavy crops of fruit. Normal Grimes on French crab stock would produce small-sized fruit if the trees set heavy crops. In the case of these dwarfish trees, however, the fruits grew rapidly and averaged larger in size that any Grimes fruits the writer had previously seen. Another outstanding difference was the premature dropping of the fruit. This occurred at least 4 weeks before the normal ripening dates of Grimes fruits. At this time the fruits were very conspicuous for their large size. Many individual fruits grew to 3⅞ inches in diameter, and weighed as much as 12½ ounces. The fruits were found to be quite mature, when judged by pressure tests of the flesh made with a Ballauf tester, patented January 9, 1934. Some tests recorded at this time were as low as 8 pounds. This softer flesh also developed visible symptoms of internal breakdown before normal Grimes fruits were mature. These fruits did not develop the normal yellow skin color of the Grimes variety, and the flavor was inferior. All of these characteristics make this an unprofitable strain of Grimes.

Records taken from 1940 through 1947 on fruits of this strain in com-

parison with similar averages for a normal strain of Grimes on French Crab, and on our own-rooted Virginia Crab stocks are as follows: The unprofitable Grimes fruits averaged 3.25 inches in diameter, 2.43 inches in height, 7.8 ounces in weight, and 15.73 pounds pressure at harvest. Normal Grimes on Virginia Crab stocks averaged 3.0 inches in diameter, 2.31 inches in height, 6.1 ounces in weight, and 19.31 pounds pressure. Normal Grimes on French Crab stocks averaged 2.64 inches in diameter, 2.06 inches in height, 5.1 ounces in weight and 21.5 pounds pressure.

To obtain additional evidence that these variations are caused by strain differences within the Grimes variety in 1942, buds were taken from trees of the unprofitable strain, and top-worked into Virginia Crab stocks. These scaffold worked Grimes buds made sufficient growth by 1946 to set a few fruits, and in 1947 a light crop was matured. These fruits developed to large size, averaging 3.5 inches in diameter, and 2.4 inches in height. The fruits on these top-worked trees began dropping prematurely, at the same time as the fruit on the initial trees. Tests indicated that the flesh was low in resistance to pressure, like similar fruits of the same strain on French Crab stocks. Judged by this light 1947 crop, the fruits of this unprofitable strain of Grimes will be as undesirable on the vigorous stock, Virginia Crab, as on French Crab seedlings.

In addition to producing undesirable fruits this strain of Grimes on French Crab seedlings is short lived. Of the original 16 trees set in 1934, 12 were dead by 1947. Two of the remaining four trees had been inarched in 1938 with own-rooted Virginia Crab stocks. These had been grafted into the Grimes trunks above the initial unions. While these inarches may have prolonged the lives of these trees the vigorous stocks did not stimulate the Grimes to increased vegetative growth. Evidence of this is shown by the fact in the fall of 1947 the two inarched Grimes measured 12 feet in height by 18 feet in width, and 10 feet in height by 12 feet in width; while the other two Grimes on their initial French Crab roots measured 12 feet high by 20 feet wide and 15 feet high by 24 feet wide.

The writer was unable to obtain definite information from the Indiana nursery regarding the source of this strain of Grimes, but several Indiana orchardists had Grimes trees which produced fruits that answered the description above recorded. From these orchardists it was learned that their original scion wood came from Ohio. Through correspondence with C. W. Ellenwood of the Ohio Agricultural Experiment Station, and I. P. Lewis, a former member of the same staff, now engaged in commercial orcharding, the writer learned that Mr. F. H. Ballou introduced a large fruited strain of Grimes, while he was a member of the Ohio Station staff. Mr. Lewis states "As it grows, topworked on Red Astrachan, it (Ballow Grimes) is not at all dwarfish. In fact it is more vigorous than our ordinary Grimes, and the fruit is about double in size, and productive. It is perhaps slightly earlier. Its greatest fault is breakdown because of its size, especially on the off-year of bearing." This description indicates a similarity in fruit characteristics to those under the writer's observation, but a difference

in tree vigor. By comparison of the Indiana strain with authentic scion material of the Ballow strain on clonal stocks the writer expects subsequently to determine whether these are similar, or the same strain.

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Tests with 2,4–Dichlorophenoxyacetic Acid for Delaying Fruit Drop of McIntosh

By L. J. EDGERTON and M. B. HOFFMAN, *Cornell University, Ithaca, N. Y.*

THE relative ineffectiveness of 2,4–dichlorophenoxyacetic acid (2,4–D) when applied as a spray for control of preharvest drop of McIntosh as compared with similar sprays of naphthaleneacetic acid has been previously reported (1). A similar ineffectiveness of 2,4–D in delaying the abscission of leaf petioles was observed when shoots of this variety were sprayed with 2,4–D (2).

During the winter of 1946–47 some preliminary tests were made with potted trees in the greenhouse to determine whether 2,4–D would manifest an effect on delaying petiole abscission of McIntosh shoots if the material were mechanically introduced into the shoots. Two methods were used in these preliminary tests. In one, shoots were cut from vigorous, 2-year-old potted trees, the leaf blades removed, and the base of the shoots immersed in a 5 ppm solution of 2,4–D for 36 hours, then the shoots were transferred to distilled water. In the other method two attached shoots on similar trees were injected near the base of the new growth with a similar solution of 5 ppm 2,4–D and the leaf blades removed above the point of injection. Additional shoots were similarly treated with naphthaleneacetic acid at the same concentration. Following these treatments it was observed that the petioles on the shoots treated with 2,4–D persisted longer than on either untreated shoots or on those treated with naphthaleneacetic acid.

Since the injection technique proved satisfactory in this preliminary work, it was decided to make a further test of this method of 2,4–D application to attached shoots on McIntosh trees in the orchard during the summer of 1947.

A McIntosh tree having a large number of vigorous shoots or "water sprouts" on the lower main limbs was selected. A small hole was drilled into the center of the shoot near the base where it was attached to the limb. A short piece of glass tubing was fitted into the opening and connected with rubber tubing to a small flask containing the solution to be injected. Fifteen leaf blades were removed from each treated shoot leaving the petioles attached. Five shoots were prepared for each treatment. The treatments consisted of 15 ml of 5 ppm solution of 2,4–D or naphthaleneacetic acid, with 15 ml distilled water introduced into the check shoots.

The data on abscission of the petioles following the injection treatments are presented in Table I. The petioles on the shoots treated by injection with 2,4–D show a lower per cent drop during the period of observation than either the check shoots or those treated with naphthaleneacetic acid.

BRANCH INJECTIONS

Since 2,4–D was effective in delaying petiole abscission of McIntosh when introduced into the stem tissue it appeared likely that it

TABLE I—PERSISTENCE OF MCINTOSH LEAF PETIOLES AS AFFECTED BY SHOOT INJECTION OF SOLUTIONS OF 2,4-DICHLOROPHENOXYACETIC ACID AND NAPHTHALENEACETIC ACID*

Treatment	Accumulated Per Cent Drop			
	Days After Treatment			
	8	11	14	17
Naphthaleneacetic acid 5 ppm	13	25	39	45
2,4-Dichlorophenoxyacetic acid 5 ppm	9	15	28	37
Check	39	56	71	79

*Solutions injected into base of shoots August 30, 1947; five shoots with total of 75 petioles per treatment.

would manifest a similar effect in delaying fruit abscission if similarly introduced into the branches.

For this test, three 18-year-old McIntosh trees were selected. Three large limbs carrying a good load of fruit were selected on each tree for the injections. Naphthaleneacetic acid and 2,4–D were dissolved in alcohol and diluted to 10 ppm with distilled water. Three liters of solution were placed in a jar which was attached to the tree above each limb to be injected. A hole was bored three quarters of the distance through each limb with a $^6/_{16}$ inch bit. Connection was made between the hole and the jar with a small rubber stopper and rubber tubing. Jars containing 3 liters of distilled water were connected with the check limbs. The test limbs on each tree received injections of naphthaleneacetic acid and 2,4–D, with the third limb as a control.

The treatments were made September 20, 1947, which was a warm clear day and the solutions were taken up by the limbs within 3 hours. This date was somewhat earlier than normal preharvest spray applications would have been made to these McIntosh trees, since very little drop was taking place. Harvesting in this block of McIntosh was started September 28. More fruit drop was noticeable at this time, and would perhaps represent the date at which spray applications of naphthaleneacetic acid would have been made.

The number of fruits remaining on the treated limbs was determined at frequent intervals and drop data computed therefrom, based on the number of fruits on the limbs at the time the treatments were started. The original number of fruits per limb varied from 100 to 150. The accumulated drop data for the treated limbs on the three trees are presented in Table II. These are summarized and represented graphically in Fig. 1.

DISCUSSION

There was no evidence of injury or abnormality to either leaves or fruit on the limbs injected with 2,4–D. The only apparent difference in addition to the lower per cent fruit drop on these limbs was that the leaves tended to remain green and persist longer than the leaves on the other limbs.

The apples from the treated limbs on one of the trees was harvested October 13 for pressure and storage tests. The fruit from the 2,4–D limb was slightly firmer than fruit from the limb injected with naph-

TABLE II—EFFECT OF LIMB INJECTIONS OF 2,4-DICHLOROPHENOXYACETIC ACID AND NAPHTHALENEACETIC ACID ON THE HARVEST DROP OF McINTOSH APPLES*

Tree	Treatment	Accumulated Per Cent Drop				
		Days After Treatment				
		6	12	17	21	24
32-1-2	Check	5.8	15.1	50.0	89.5	95.3
	Naphthaleneacetic acid	2.6	3.3	3.3	8.5	13.1
	2,4-Dichlorophenoxyacetic acid	1.4	2.9	2.9	2.9	3.6
32-1-4	Check	9.3	16.3	25.6	69.8	90.7
	Naphthaleneacetic acid	2.9	2.9	4.3	5.8	15.9
	2,4-Dichlorophenoxyacetic acid	1.2	1.2	2.4	2.4	3.5
32-1-6	Check	3.4	5.6	11.2	34.8	43.8
	Naphthaleneacetic acid	0.9	0.9	1.9	12.4	14.3
	2,4-Dichlorophenoxyacetic acid	0.8	0.8	1.7	2.5	4.2

*3 liters 10 ppm solution injected into each limb September 20, 1947.

thaleneacetic acid. No abnormality was apparent in flavor or quality of the apples. The fruit from the treated limbs on the other two trees was harvested October 25. At this time many of the apples on both the 2,4–D and naphthaleneacetic acid limbs were split but even at this date, 35 days after the treatments were made, the 2,4–D injections had shown effective drop control as indicated in Fig. 1.

These fruit drop data indicate that 2,4–D has a marked effectiveness

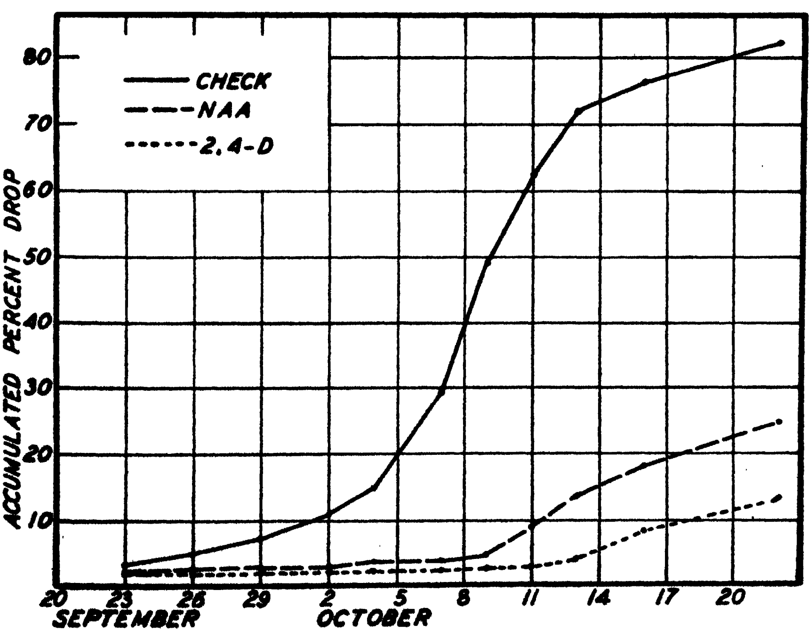

FIG. 1. Curves showing the average accumulated per cent fruit drop of McIntosh apples following limb injections of 2,4–D and naphthaleneacetic acid (NAA). Limbs injected with 3 liters 10 ppm solution on September 20, 1947.

in delaying fruit abscission of McIntosh when it is introduced into the branch by injection. Its greater effectiveness as compared with naphthaleneacetic acid is similar to the previously observed results of 2,4–D spray applications on Winesap (1) and Stayman Winesap (3).

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A Comparison of Naphthaleneacetic Acid and 2,4–Dichlorophenoxyacetic Acid Sprays for Controlling Pre-Harvest Drop of Bartlett Pears

By L. P. Batjer, A. H. Thompson and Fisk Gerhardt, *U. S. Department of Agriculture, Wenatchee, Wash.*

The high degree of effectiveness of 2,4–dichlorophenoxyacetic acid (2,4–D) in preventing fruit drop of Winesap and Stayman Winesap apples has been reported (1). Likewise attention has been called to the selective nature of this chemical with its failure to have any appreciable effect in preventing drop on a number of important commercial apple varieties (1, 3). The purpose of this paper is to present the results of a 3-year comparison of 2,4–D and naphthaleneacetic acid (hereafter written NAA) in retarding the pre-harvest drop of Bartlett pears.

Experiments in 1945 and 1946

In 1945, 16 trees (2 trees per treatment) were sprayed with four concentrations each of 2,4–D and NAA (Table I). The 1946 tests, also given in Table I, were applied to seven randomized trees per treatment. Sprays during both years were applied approximately 2 weeks before harvest with a portable power sprayer operating with a pump pressure of 500 pounds. The chemicals were dissolved in a small amount of ethyl alcohol before being added to the water in the spray tank. A light summer oil emulsion was used with each treatment at the rate of 1 pint per 100 gallons.

TABLE I—The Effect of Different Concentrations of Naphthaleneacetic Acid and 2,4–Dichlorophenoxyacetic Acid in Controlling the Pre-Harvest Drop of Bartlett Pears

Treatment	Concentration (Ppm)	Accumulated Per Cent Drop	
		1945	1946
NAA	2.5	1.0	0.38
NAA	5.0	1.1	0.32
NAA	10.0	0.5	—
NAA	20.0	1.1	—
2,4-D	2.5	0.8	0.36
2,4-D	5.0	0.3	—
2,4-D	10.0	1.5	—
2,4-D	20.0	1.2	—
Unsprayed	—	5.0	2.5

The data obtained in 1945 and shown in Table I were regarded as preliminary in nature since each treatment represented only two trees per treatment. The per cent drop, however, for the various 2,4–D treatments indicated that this chemical was as effective in retarding the drop of Bartletts as NAA. The data further suggested little, if any, difference in effectiveness of the various concentrations of either 2,4–D or NAA.

Of considerable interest and significance was the amount of injury resulting from some of the treatments. With 2,4–D, no injury was obtained with the 2½ ppm spray, but all other treatments of this chemi-

cal caused injury which was roughly proportional to the concentration. Premature yellowing of spur leaves in the shaded portions of the trees was evident 2 to 3 weeks following treatments. Within 10 days after the sprays were applied, trees receiving the 10- and 20-ppm treatments became noticeably flagged as if suffering acutely for lack of water. Premature defoliation occurred on these trees. In the spring of 1946, from 75 to 90 per cent of the leaf and flower buds were found to be dead on the trees receiving the 20-ppm sprays; a lesser but a significant number of buds were killed on those trees sprayed with 10 ppm of 2,4–D. The trees sprayed with 5 ppm exhibited very few dead buds but some of the fruit and foliage was seriously malformed. The weakest spray of 2,4–D (2½ ppm) resulted in no injury in either year.

Surprisingly enough the NAA at 10 ppm and to a greater extent the 20-ppm treatment resulted in premature yellowing of some leaves and varying degrees of early defoliation. This injury from the 10-ppm treatment did not affect the crop the following year, but nearly one-half of the flower buds failed to develop as a result of spraying with a concentration of 20 ppm.

The fruit drop data obtained in the 1946 (Table I) experiment substantiate those obtained in 1945 for similar treatments. While the fruit drop from unsprayed trees was only 2.5 per cent, yet the 2,4–D (2½ ppm) and NAA at both 2½ and 5 ppm resulted in an appreciable and uniform reduction of drop. As was true in the 1945 experiment, no injury resulted from any of these treatments either in the year applied or the year following.

1947 Experiment

Each treatment shown in Table II consisted of nine randomized Bartlett trees selected for uniformity of size and crop (yield varied from 20 to 25 boxes per tree). Sprays were applied July 17 and the first picking which constituted about one-half of the total crop was made August 5. The second or "clean up" picking was made on August 19. The amount of fruit drop from August 6 to August 19, expressed in percentage of fruit remaining on the tree after the first picking, is shown in Table II. Other data recorded at the time of the second picking included: (a) the amount of fruit dropped or knocked off by pickers during the harvest operation; (b) the firmness of the fruit as determined by the pressure tester; and (c) the percentage of fruit which was predominately yellow and soft. At the time of the second picking a composite sample of 180 fruits (20 fruits per tree) was selected from trees receiving each treatment and stored at 31 degrees F until November 21. On this date, a sample of 25 fruits from each lot were pressure tested for firmness. After separating the fruits of each lot into two classes on the basis of color, the fruit was ripened at 65 degrees F for 7 days and examined for core breakdown.

The data presented in Table II show a very high degree of effectiveness for all treatments in preventing fruit drop. The tenacity with which the fruit was held as a result of the sprays is further indicated by the greatly reduced amount of fruit which was knocked off by pickers during routine harvest operations. No evidence of injury was ob-

TABLE II—EFFECT OF 2,4-DICHLOROPHENOXYACETIC ACID AND NAPHTHALENEACETIC ACID SPRAYS ON FRUIT DROP AND MATURITY OF BARTLETT PEARS

Treatment	Concentration (Ppm)	Fruit Drop (Per Cent S.E.M.)	Fruit Knocked Off By Pickers (Per Cent)	Ripe Fruit At Harvest (Per Cent)	Firmness (Pounds Pressure) Aug 19	Firmness (Pounds Pressure) Nov 21	Yellow* Fruit Nov 21 (Per Cent)	Core† Breakdown (Per Cent)
2,4-D.....	2.5	0.5±0.11	1.5	1.6	18.5	16.3	37	2.4
NAA.....	2.5	1.3±0.29	1.9	2.5	18.5	16.1	33	1.7
NAA......	10.0	0.9±0.15	1.4	3.3	18.2	16.0	60	5.8
Unsprayed	—	26.6±3.29	9.1	0.6	18.7	16.3	22	1.5

*All fruit when stored was green in color. Figures represent the amount of fruit which had changed from green to predominately yellow during storage.
†After storage at 31 degrees F for 94 days and ripening at 65 degrees F for 7 days.

served on trees receiving either the 2,4-D or NAA at 2½ ppm. However, at harvest time every tree sprayed with 10 ppm of NAA exhibited a moderate number of premature yellow leaves throughout the inner portion of the tree.

The effect of the sprays on fruit maturity is shown in Table II. While the differences are not great, yet 10 ppm of NAA appeared to hasten maturity as indicated by the greater amount of ripe fruit at harvest, more fruits showing a predominant yellow color when removed from storage, a higher percentage of core breakdown, and slightly less firmness both at harvest time and when removed from storage. Fruits of the 2½-ppm treatment of both 2,4-D and NAA were slightly more advanced in maturity than check fruits though not significant as measured by some of the standards that were used to determine maturity.

DISCUSSION

In all of the 3 years tested, 2,4-D proved to be as effective as NAA in reducing the drop of Bartlett pears. In the 1945 experiment, injury which was roughly proportional to the concentration was obtained with all 2,4-D sprays stronger than 2½ ppm. The latter concentration caused no injury in any of the experiments and its very high degree of effectiveness would suggest that 2,4-D might be effective on Bartletts when used at even a weaker strength. While the present experiments indicate 2,4-D to be promising as a pre-harvest spray for Bartlett pears, more extensive work is needed before the use of this chemical on Bartletts can be adequately evaluated.

Relative to the effect of hormone sprays on pear maturity Gerhardt (2) has shown that only when Bartlett harvest is delayed well beyond optimum picking maturity, NAA sprays (10 ppm) resulted in a stimulatory effect on ripening which was greater than could be accounted for merely by indirect effects or differences in drop of the most mature fruit from sprayed and unsprayed trees. In the 1947 experiment the pears were harvested at a firmness of 18 pounds pressure which is regarded in the maximum range of acceptable maturity; yet, the hormone sprayed fruit, particularly that receiving 10 ppm of NAA, seemed to be more advanced in maturity than unsprayed fruit. As compared with the weaker concentration, the greater influence on fruit

ripening of the 10-ppm spray would seem to be at least in part a direct effect rather than entirely indirect since both treatments resulted in virtually the same control of drop.

The fact that the 10-ppm spray in two different tests resulted in slight injury to the foliage indicates that this concentration is at or near the critical range of tolerance for Bartlett pears. The data clearly indicate that under Northwest conditions, NAA at 2½ ppm is about as effective in controlling drop as a standard strength 10 ppm spray of this chemical. From the commercial standpoint, therefore, it would seem highly desirable to adopt the weaker spray particularly since the stronger sprays may result in foliage injury as well as having possibly a greater stimulatory effect on fruit maturity.

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Effectiveness of Different Concentrations of 2,4–D As a Preharvest Spray for Stayman Winesap Apples

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The use of 10 parts per million or more of the volatile esters of 2,4–D as sprays to prevent harvest drop of Winesap and Stayman Winesap apples in 1946, caused injury to the foliage of the sprayed trees that was evident in the spring of 1947. The injury was very slight or absent when the nonvolatile salts or acid of 2,4–D were used at 10 ppm. This injury has been described by Teske and Overholser (3) and by Moon, Regeimbal, and Harley (2). While in most cases the injury was not considered very serious, it seemed advisable to test lower concentrations of these sprays to see if harvest drop could be controlled by a concentration that would cause no injury the following year. This paper gives the fruit-drop results in an experiment set up in August 1947 to test that possibility.

Materials and Methods

Seventy Stayman Winesap trees, each having an estimated crop of 10 bushels or more, were selected and divided into 14 groups of five trees each. Two of these groups were assigned to each of seven treatments and randomized so that no two groups receiving the same treatment were in the same general area of the orchard. The treatments were: (a) 2,4–D (acid) 10 ppm; (b) 2,4–D (acid) 5 ppm; (c) 2,4–D (acid) 2.5 ppm; (d) Weedicide (73 per cent diethanolammonium 2,4–dichlorophenoxyacetate) 20 ppm (10 ppm 2,4–D equivalent); (e) butyl 2,4–dichlorophenoxyacetate, 2.5 ppm; (f) butyl 2,4–dichlorophenoxyacetate, 1 ppm; and (g) control, no spray.

All sprays were applied with a portable outfit using 600 pounds pressure. A spray gun with a number 14 disc was used from the spray tower and a six-nozzle boom with number 4 discs was used from the ground. An average of 15 to 18 gallons of spray per tree was used, with 30 ml of 30 per cent Santomerse per 100 gallons of spray mixture in all sprays as a wetting agent. The sprays were applied on August 26, when the temperature was in the low 90's. A rather heavy thundershower occurred in the evening after the sprays were dry and the following day was rather cool and foggy, with the temperature in the lower 70's.

Results

It may be seen from the examination of Table I that the most effective treatments were the Weedicide and the 10 ppm 2,4–D sprays. The average fruit drop from the 10 ppm 2,4–D, acid plots was approximately two and one-half times as great as that from the Weedicide plots, but due to rather great individual tree variability this differ-

[1]The authors wish to express their appreciation to Mr. I. Z. Musselman of the Orrtanna Canning Company, Orrtanna, Pennsylvania, and his staff for their cooperation in making this experiment possible.

ence is not statistically significant. All concentrations of sprays used had some effect; but the drop from all plots except those that had received either Weedicide or 10 ppm 2,4–D acid was considered excessive, and the commercial value of the weaker concentrations seems questionable.

TABLE I—THE EFFECT ON FRUIT DROP OF STAYMAN WINESAP OF SPRAYS OF DIFFERENT CONCENTRATIONS OF 2,4–DICHLOROPHENOXYACETIC ACID AND SOME RELATED COMPOUNDS

Treatment	Average Total Drop to October 23, 1947 (Per Cent)*
2,4-dichlorophenoxyacetic acid, 10 ppm	17.6
2,4-dichlorophenoxyacetic acid, 5 ppm	35.2
2,4-dichlorophenoxyacetic acid, 2.5 ppm	60.5
Butyl 2,4-dichlorophenoxyacetate 2.5 ppm	35.3
Butyl 2-4,dichlorophenoxyacetate 1.0 ppm	43.8
Weedicide, 20 ppm (10 ppm 2,4-D equivalent)	6.9
Control (no spray)	80.5

*Averages are for 10 trees; difference necessary for significance at 5 per cent level: 12.7 per cent

In spite of the relatively high intensity of effect on fruit abscission of the Weedicide, there was no noticeable effect on fruit maturity. The after-effects on the trees, however, will not be known until growth starts in the spring of 1948.

It was not considered safe to try sprays of the butyl ester at concentrations above 2.5 ppm because former work by the authors had shown that a concentration of 10 ppm of this substance had marked effect on hastening fruit maturity (1), and also that this concentration caused rather serious injury to the trees (2). The fruit-drop figures for the three concentrations of 2,4–D acid used would seem to indicate that the intensity of effect of this material within the range tested, could be expected to be closely proportional to the concentration of spray used.

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The Transmission of Effect of Naphthaleneacetic Acid on Apple Drop as Determined by Localized Applications

By L. P. Batjer and A. H. Thompson, *U. S. Department of Agriculture, Wenatchee, Wash.*

In applications of growth substances to plants, the most pronounced effects are usually observed to take place at or near the point of application. Since the advent of hormone sprays to reduce fruit drop, the question of transmission of effect of these sprays has repeatedly been raised. On the basis of numerous experiments using the limb unit method of applying treatments of naphthaleneacetic acid (3, 4), it seems certain that sprays applied to small limbs have no measurable influence on the fruit of adjacent limbs of the same tree. However, the extent to which the effect is transmitted from spur to spur, and the role the foliage plays in receiving and absorbing the spray chemical and transmitting the effect to fruit on the same spur or nearby spurs has never been adequately investigated. From practical aspects the need for basic information on these points has arisen because of new methods of applying hormone sprays which do not result in as thorough coverage as conventional methods of application.

Effect of Localized Applications on Fruit Drop

Seventy-five groups of four adjacent fruiting spurs each were designated for treatment on a vigorous tree of the Milton variety; 70 groups of four fruiting spurs each were similarly assigned on a typical tree of the Oldenburg (Duchess) variety. Each fruit was individually tagged. The different treatments indicated in Table I were applied approximately 10 days in advance of harvest to one fruiting spur in each group. A 10 ppm solution of naphthaleneacetic acid was used. In the two treatments involving application of the solution either to the fruit stem and cluster base or to leaves only, the solution was carefully applied with a camel's hair brush. A hand atomizer was used in applying the solution where the entire spur (leaves, fruit stems, and cluster base) was treated. In no case were treated fruits closer than 6 inches apart.

As might be expected (Table I), greater reduction in drop was

TABLE I—Effect of Localized Applications of Naphthaleneacetic Acid (10 Ppm) on Harvest Drop of Oldenburg and Milton Apples

Place of Spray Application	Number of Fruiting Spurs Treated	Variety	Accumulated Per Cent Drop—Days Following Treatment		
			12	14	18
Fruit stem and cluster base only	75	Milton	21	34	73
Foliage only	75	Milton	10	18	57
Fruit stem, cluster base and foliage	75	Milton	7	8	48
Untreated	75	Milton	29	46	80
Fruit stem and cluster base only	70	Oldenburg	—	17	—
Foliage only	70	Oldenburg	—	9	—
Fruit stem, cluster base and foliage	70	Oldenburg	—	3	—
Untreated	70	Oldenburg	—	24	—

obtained when the entire spur was sprayed. In both varieties the treatment involving leaves only was much more effective than when the naphthaleneacetic acid was applied only to the fruit stem and cluster base. The latter treatment was only slightly better than the untreated checks.

Effect of Localized Applications on Untreated Adjacent Fruits

Conventional Concentration (Naphthaleneacetic Acid, 10 Ppm):— In order to determine the extent to which the effect of naphthaleneacetic acid is transmitted, treatments indicated in Table II were applied to fruiting spurs of a single Oldenburg apple tree on July 8. Spurs (or components of spurs) receiving treatment were sprayed thoroughly (foliage, fruit stem, and cluster base) with a hand atomizer. Each spur sprayed was so shielded as to avoid any possible drift of the spray mist to adjacent tissues. The presence of numerous compound spurs with two fruiting branches (with cluster bases not more than 1 inch apart) afforded an opportunity to determine whether sprays applied to one component of the spur would have any effect in retarding drop of the other fruit borne on the same spur but originating from a different flowering cluster. A similar number of simple fruiting spurs were sprayed to note what effect the naphthaleneacetic acid treatment would have on adjacent fruiting spurs on the same limb. Check fruits were selected on spurs at least 12 inches distant from a treated spur.

It may be seen from the data in Table II that the amount of fruit drop from the untreated components of the compound fruiting spurs was considerably less than the drop from the check spurs. While greater effectiveness was obtained on the treated portion of these spurs, the data clearly indicate an appreciable transmission of the stimulus from treated to untreated portions of the same spur. However, there was little, if any, transmission of effect from a treated spur to an adjacent non-treated spur (check spurs) on the same limb.

TABLE II—Effect of Naphthaleneacetic Acid (10 Ppm) Applied to Fruiting Spurs of Oldenburg Apple on the Subsequent Drop of Treated and Adjacent Non-Treated Fruits

Type of Spur and Location	Sprayed	Number of Spurs Treated	Accumulated Per Cent Drop—Days Following Treatment				
			8	12	15	19	21
Simple fruiting spur	Yes	45	0	0	0	9	13
Fruit spur adjacent to above*	No	45	10	19	33	48	52
One component of compound fruiting spur	Yes	46	0	0	4	7	9
Other component of compound fruiting spur	No	46	4	11	17	26	33
Fruiting spur† (check)	No	91	16	27	36	51	54

*Fruiting spur not more than 3 inches distant from a treated spur on the same limb.
†Fruiting spur approximately 12 inches distant from a treated spur.

Airplane Concentration (Naphthaleneacetic Acid, 2400 Ppm):— With the airplane, which is used extensively in the Northwest in applying hormone sprays, it is customary to apply a solution of 2400 ppm of naphthaleneacetic acid in a 40 per cent oil emulsion at the approxi-

mate rate of 5 gallons per acre. With optimum flying conditions this method results in a deposit of 10 to 20 minute droplets of solution on each well-exposed leaf. However, much of the foliage receives considerably less than this amount and many of the leaves in the inside portion of the tree are not reached at all.

In order to study the transmission of effect of a concentrated solution such as the airplane applies, an attempt was made to simulate a typical airplane type of deposit by using a micro-pipette to apply the hormone solution. Ninety groups of three fruits each were selected on a young Early McIntosh tree. The spur leaves of one fruit in each group received 15 minute droplets of the hormone solution per leaf. The droplets were approximately the same size as those ordinarily applied by the airplane. One untreated fruiting spur in each set (less than 3 inches distant from a treated spur) served to determine the extent to which the effect of the hormone might be transported. The third fruiting spur in each group was located approximately 12 inches from the treated spur and was designated as an untreated check. Fruits were selected and treated July 21; the fruit was harvested on August 4:

Results presented in Table III show no difference in fruit drop

TABLE III—Effect of Naphthaleneacetic Acid (2400 PPM) Applied to Foliage of Early McIntosh Fruiting Spurs, on Subsequent Fruit Drop and Maturity of Treated and Adjacent Fruits

Treatment	Fruit Drop (Per Cent)	Stage of Fruit Maturity When Harvested					
		Ripe			Unripe		
		Fruit (Per Cent)	Pounds Pressure	Red Color (Per Cent)	Fruit (Per Cent)	Pounds Pressure	Red Color (Per Cent)
Fruits on treated spurs	5	69	12.5	95	31	16.8	42
Fruits adjacent to treated spurs*	11	2	—	95	98	17.3	40
Check†	11	2	—	95	98	17.7	34

*Fruiting spurs not more than 3 inches distant from a treated spur on the same limb.
†Fruiting spurs approximately 12 inches distant from a treated spur.

between the fruits adjacent to the treated spurs and those further removed (checks). Of considerable interest is the very pronounced effect of the treatment on the color and maturity of the fruit borne on the treated spurs. It will be noted from the data that this stimulatory effect of the hormone is confined entirely to fruits of the treated spurs. There was no indication either by fruit color or maturity that such effects were transmitted to adjacent untreated spurs.

Discussion

The data presented, while admittedly limited, seem to establish clearly the foliage as the chief means of transporting the spray stimulus responsible for retarding fruit drop. Under conditions of this experiment, applications made solely to fruit stems and cluster bases had only a slight effect, although when these tissues in addition to the foliage were treated the reduction in fruit drop was greater than when the foliage alone was sprayed.

Regarding the transmission of effect from one fruit to another when one component of a compound spur was treated, fruit drop from the other component seemed to be appreciably reduced though the degree of reduction was considerably less than on the treated portion. Since a very minor proportion of the fruit of most apple varieties is borne on compound fruiting spurs, very little practical significance can be placed on this type of stimulus transmission. There seemed to be little or no effect transmitted from a treated single spur to an untreated spur close by. Such was the case with either a conventional spray (10 ppm) or a highly concentrated one (2400 ppm) as the airplane employs. Therefore, these results would seem to support earlier conclusions (1) that thorough spray coverage is necessary in order to obtain the most effective results from hormone sprays.

The marked stimulatory effect on fruit maturity of the 2400 ppm treatment (Table III) was an unexpected result in this experiment. With the technique used a greater than average application was undoubtedly made, though it is believed that some well-exposed foliage and fruit receive as much or more naphthaleneacetic acid when regular commercial airplane applications are made. A moderate degree of direct stimulation from conventional hormone sprays on summer apples has been reported by the senior author (2), but no visible effects on maturity were observed with 10 ppm treatments in the present experiments. In the case of fall and late fall varieties no stimulation of maturity has been reported as a result of using conventional hormone sprays, provided harvest is not delayed beyond commercial picking maturity (5). Whether or not heavy deposits of the spray solution made by the airplane on well-exposed limbs of these varieties will advance maturity, remains to be determined.

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Some Residual Effects of Sprays Containing 2,4–D on Apple Trees

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In the spring of 1947 some injury was observed by the authors on Stayman Winesap and Winesap trees that had been sprayed with 2,4–dichlorophenoxyacetic acid (2,4–D) in the fall of 1946.

On November 9, 1946, a small block of apple trees was airplane-sprayed with 8100 ppm 2,4–D in an oil emulsion to determine the effect of this drastic treatment on the trees. Stayman Winesap and Winesap trees so treated held their leaves well into the winter after all leaves were dead, and long after untreated trees were completely defoliated. In the spring of 1947 numerous leaf petioles could be found still attached to the branches, even though the blades had been broken off during the winter. No other effect was evident on these trees until growth started, when it was noticed that they showed typical signs of delayed foliation. The primary leaves on numerous spurs were badly deformed and showed typical epinasty. This injury has been fully described by Teske and Overholser (2).

Fig. 1 shows typical terminals of sprayed and unsprayed Stayman Winesap trees as they appeared on April 30, 1947.

A few of the lateral buds on these terminal shoots had been killed, as had also some of the weaker spurs on older branches. Leaves on practically all growth occurring later in the season appeared normal, but the great number of stunted and malformed leaves gave the appearance of having sparse foliage throughout the season. Rome Beauty and Delicious trees similarly treated showed no effect whatsoever.

Fig. 1. Typical terminals of Stayman Winesap. Left, airplane application 8100 ppm 2,4–D, November 9, 1946. Right, unsprayed. Photographed April 30, 1947.

In another block of Stayman Winesap trees used in 1946 to test the efficiency of several compounds of 2,4–D in controlling fruit drop (1), rather severe injury to the foliage was evident, early in June 1947, on trees that had received on August 29 and September 11 ground-spray applications of 10 ppm of either the butyl ester of 2,4–D or the commercial weed killer. Fig. 2 shows the injury caused by the butyl ester

Fig. 2. Injury by butyl ester of 2,4–D to Stayman Winesap; 10 ppm spray applied both August 29 and September 11, 1946. Photographed June 10, 1947.

spray. Some delayed foliation was evident on these trees, but there were not nearly so many bare terminals as was the case where the trees had received the 8100 ppm 2,4–D airplane spray. Malformed and stunted leaves on these trees were even more widely distributed than on the airplane-sprayed trees, and it was hard to find a normal-appearing primary leaf on any spur. All blossoms and small fruits killed by frost on May 9 to 11 were still adhering tightly to the spurs, giving the impression that the spray had caused a poor set of fruit, but examination of unsprayed trees showed that they did not seem to have set a better crop than the sprayed trees. A careful analysis, however, of the relationship between sprays of 2,4–D and fruit-set response could not be made because of frost-injury variability. Trees that had received a single spray of 10 ppm of either the butyl ester or Weedone were injured, but the injury was not so severe as on those upon which

the double application was made. Trees that had received sprays of 2,4-D acid, or the sodium or the ammonium salt of 2,4-D, showed very little injury, although some epinasty was found on the plots receiving double sprays of these substances. Arkansas (Black Twig) trees in the same orchard and receiving the same spray treatments as the Stayman Winesap trees showed no injury whatsoever.

The authors were unable to find severe damage in commercial orchards that had received the usual 10 ppm 2,4-D stop-drop spray. The only indication of injury in any of these orchards examined was a few deformed leaves on an occasional spur on a few scattered trees.

The fact that the dead young fruits were still adhering tightly to the spurs of the sprayed Stayman Winesap trees on June 10 after the fruit had fallen from the unsprayed trees made it seem advisable to keep records on some of these trees again to see if the spray would still be effective in preventing autumn fruit drop the next year after that in which the application was made. Trees were selected in four of the plots and drop records were taken on them until harvest on October 23, 1947. The average per cent total fruit drop for these plots for 1946 and the average per cent total fruit drop for the same trees in 1947 are given in Table I.

TABLE I—AVERAGE PER CENT TOTAL DROP FOR 1946 AND 1947 OF STAYMAN WINESAP APPLES FROM TREES SPRAYED IN 1946 ONLY

Treatment	Date of Treatment (1946)	Average Total Drop to Oct 30, 1946	Average Total Drop to Oct 23, 1947
Control	———	52.4 ±13.3	61.2 ±4.5
2,4-D acid 10 ppm + Carbowax 1500 0.25 per cent	Aug 29	11.4 ±0.6	33.2 ±5.6
2,4-D 10 ppm + Bordeaux 2-4-100	Aug 29	29.8 ±13.1	38.6 ±8.6
2,4-D 10 ppm + Bordeaux 2-4-100	Aug 29 and Sep 11	10.6 ±4.7	34.0 ±0.7

These results indicate that while the spray was not so effective in 1947 as it had been in 1946, the year of application, it still had a marked effect in reducing the harvest drop of apples for a full year after it had been applied.

In the general application of sprays containing 2,4-D to reduce harvest drop of Stayman Winesap and Winesap apples, the following deductions, based on experimental evidence and observations, are probably justified at the present time: (a) Concentrations exceeding 10 ppm of the acid or of the salts will most likely cause some injury to primary leaves in the following growing season. Even with 10 ppm, some spur leaves have evidenced epinastic responses. (b) Until more evidence is available, spray formulations containing the esters of 2,4-D should be avoided in commercial applications. (c) A reduction in fruit drop one year following the application of 2,4-D may restrict the use of experimental trees for stop-drop experimental spraying to those responsive varieties having an accurately known spray history for at least two growing seasons. (d) No leaf abnormalities were found on varieties that were unaffected by 2,4-D as a harvest spray.

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DDT Residue and Its Removal From Apples and Pears[1]

By KENNETH C. WALKER, *Tree Fruit Experiment Station, Wenatchee, Wash.*

DDT sprays for codling moth control were adopted in approximately 90 per cent of the apple and pear orchards in North Central Washington in 1947. The use of DDT in large quantities was anticipated in 1946 and studies were conducted to determine the residue problem (1). It was shown that the DDT residue on fruit at harvest time should not exceed the present informal tolerance of the Food and Drug Administration of 7 parts per million (ppm) if a program similar to that recommended by the State College of Washington (2) was followed. With the general adoption of DDT as a codling moth spray, some orchardists failed to follow the recommended spray program and consequently, high DDT residue on some fruit presented a problem.

RESULTS OF COMMERCIAL WAREHOUSE SURVEY

One hundred and twenty-seven apple samples were collected from 49 different growers and 10 pear samples from eight growers. The DDT residue was determined by removing the DDT from these samples with toluene and analyzing the toluene for total chlorine by a modification of the Gunther method. The results are presented in Table I.

TABLE I—DISTRIBUTION OF DDT RESIDUE ON UNWASHED FRUIT AT HARVEST TIME

Recommended Spray Programs			Non-Recommended Spray Programs	
No. Samples			No. Samples	
Apples	Pears	DDT (Ppm)	Apples	DDT (Ppm)
2	1	0-0.9	2	3-3.9
10	5	1-1.9	1	4-4.9
29	2	2-2.9	2	5-5.9
19	1	3-3.9	2	6-6.9
17	1	4-4.9	6	7-7.9
16	-	5-5.9	5	8-8.9
5	-	6-6.9	2	9-9.9
3	-	7-7.9	1	18-18.9
3	-	8-8.9	-	—
1	-	10-10.9	-	—
1	-	11-11.9	-	—

Where the recommended spray program was followed in commercial orchards, 92.4 per cent of the apple samples submitted for analysis were below the tolerance. Where other than the recommended spray program was followed in commercial orchards, 33.3 per cent of the apple samples submitted for analysis were below the tolerance. Of the total 127 apple samples submitted for analysis irrespective of the spray

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programs, 82.8 per cent were below the tolerance. All pear samples received were below the tolerance and were from recommended spray programs.

EXPERIMENTAL RESULTS

Effect of Late Season Application of DDT, DDT-Oil Mixtures and Oil Sprays:—The experimental spray programs shown in Table II were applied to determine the effect of such sprays on the DDT residue at harvest time and to obtain fruit at harvest time that would carry a high DDT residue for experimental washing studies.

TABLE II—SPRAY PROGRAM AND RESIDUE AT HARVEST TIME

50 Per Cent DDT (Pounds Per 100 Gallons of Water)

Spray Date	Plot 1	Plot 2	Plot 3
Bartlett Pears			
May 10	2.0	2.0	2.0
Jun 14	2.0	2.0	2.0
Jul 9	1.5	1.5	1.5
Jul 17	0.38*	0.38*	0.38*
Aug 2	—	2.0	2.00**
Residue	2.8 ppm	10.6 ppm	22.1 ppm

Fruit harvested Aug 6, 1947

Spray Date	Plot 4	Plot 5	Plot 6
Buerre D'Anjou Pears			
Mar 10	2.0	2.0	2.0
Jul 14	2.0	2.0	2.0
Jul 9	1.5	1.5	1.5
Jul 17	0.38*	0.38*	0.38*
Aug 20	—	2.0	2.0**
Residue	3.2 ppm	6.7 ppm	11.7 ppm

Fruit harvested Aug 27, 1947

Spray Date	Plot 7	Plot 8	Plot 9	Plot 10
Starking Delicious Apples				
May 14	2.0	2.0	2.0	2.0
June 3	1.5	1.5	1.5	1.5
Jul 12	1.5	1.5	1.5	1.5
Jul 24	0.38*	0.38*	0.38*	0.38*
Aug 19	—	2.0	2.0**	3 quarts oil†
Residue	2.9 ppm	7.3 ppm	12.3 ppm	5.6 ppm

*Applied as a red spider mite spray containing 25 per cent DDT.
**2 quarts light grade summer petroleum oil applied with the DDT.
†3 quarts light grade summer petroleum oil applied alone; fruit harvested Sep 8, 1947.

The additional spray of 2 pounds of 50 per cent DDT (plot 2) over the recommended spray program (plot 1) on Bartlett Pears increased the DDT residue at harvest time from 2.8 ppm to 10.6 ppm. The addition of 2 quarts of light grade summer petroleum oil to the 2 pounds of 50 per cent DDT (plot 3) further increased the DDT residue to 22.1 ppm.

The additional spray of 2 pounds of 50 per cent DDT (plot 5) over the recommended spray program (plot 4) on Buerre D'Anjou Pears

increased the DDT residue at harvest time from 3.2 ppm to 6.7 ppm. The addition of 2 quarts of light grade summer petroleum oil to the 2 pounds of 50 per cent DDT (plot 6) further increased the DDT residue to 11.7 ppm.

The additional spray of 2 pounds of 50 per cent DDT (plot 8) over the recommended spray program (plot 7) on Starking Delicious Apples increased the DDT residue at harvest time from 2.9 ppm to 7.3 ppm. The addition of 2 quarts light grade summer petroleum oil to the 2 pounds of 50 per cent DDT (plot 9) further increased the DDT residue to 12.3 ppm. When a spray of 3 quarts of light grade summer petroleum oil was applied (plot 10) the DDT residue remaining on the fruit at harvest time was 5.6 ppm or an increase over fruit that did not receive any additional sprays of 2.7 ppm.

Experimental Washing Studies

Experimental washing studies with various wetting agents, detergents and chemical baths were conducted on fruit from experimental spray plots 2, 3, 5, 6, 7, 9 and 10. Fruit from plots 1, 4 and 8 were not used. The size and quantity of fruit from these plots made them unusable as all fruit had to be smaller than $2^{13}/_{16}$ inches in order to pass through the constricted neck of the jars used in analyzing the fruit. The spray programs for these plots are given in Table I. The results of the washing studies are presented in Tables III, IV and V.

TABLE III—Effect of Commercial Detergents on DDT Residue Removal From Bartlett Pears

Washing Treatment	Plot 2: Mean DDT After Treatment (Ppm)	Plot 2: Mean Amount Removed (Ppm)	Plot 2: Replicates	Plot 3: Mean DDT After Treatment (Ppm)	Plot 3: Mean Amount Removed (Ppm)	Plot 3: Replicates
None	10.6	—	4	22.1	—	4
Water at 64 degrees	7.1	3.5‡	4	20.1	2.0	4
1/20 per cent D-40* at 90 degrees F	6.2	4.4§	4	21.7	0.4	4
¼ pt. Ortho Wash**/270 gals at 90 degrees F	6.6	4.0§	4	19.4	2.7	4
1 pt. Ortho wash/270 gals at 90 degrees F	6.6	4.0§	4	20.3	1.8	4
½ pound RE-555**/270 gals at 90 degrees F	6.9	3.7‡	4	20.1	2.0	4
1 per cent F-W-3† at 61 degrees F	6.3	4.3§	5	21.2	1.0	6
1 per cent F-W-3 at 90 degrees F	6.1	4.5§	3	19.6	2.5	2
1 per cent F-W-3 at 100 degrees F	6.0	4.6§	3	21.2	0.9	2

*Product of Orinite Chemical Company.
**Product of California Spray Chemical Company.
†Product of Balab Corporation.
‡Significant at 5 per cent level.
§Significant at 1 per cent level.

The washing treatments on plot 2 removed a significant amount of DDT residue from all samples and reduced the DDT residue to less than the present informal tolerance in all cases except the water wash at 64 degrees F. There was no significant difference between treatments. All treatments on plot 3 failed to remove a significant amount of DDT residue and there was no significant difference between treatments.

TABLE IV—EFFECT OF SODIUM SILICATE AND A COMMERCIAL DETERGENT ON DDT RESIDUE REMOVAL FROM BUERRE D'ANJOU PEARS

Washing Treatment	Plot 5			Plot 6		
	Mean DDT After Treatment (Ppm)	Mean Amount Removed (Ppm)	Replicates	Mean DDT After Treatment (Ppm)	Mean Amount Removed (Ppm)	Replicates
None	6.7	—	4	11.7	—	4
50 pounds Sodium silicate at 78 degrees F, and 1 per cent F-W-3 at 78 degrees F	3.4	3.3*	4	10.5	1.2	4
50 pounds Sodium silicate at 90 degrees F, and 1 per cent F-W-3 at 78 degrees F	9.1	-2.4	4	12.4	-0.7	4
50 pounds Sodium silicate at 90 degrees F, and 1 per cent F-W-3 at 90 degrees F	4.7	2.0	4	12.4	-0.7	4

*Significant at 5 per cent level.

TABLE V—EFFECT OF VARIOUS WASHING TREATMENTS ON DDT RESIDUE REMOVAL FROM STARKING DELICIOUS APPLES

Washing Treatment	Plot 7			Plot 9			Plot 10		
	Mean DDT After Treatment (Ppm)	Mean Amount Removed (Ppm)	Replicates	Mean DDT After Treatment (Ppm)	Mean Amount Removed (Ppm)	Replicates	Mean DDT After Treatment (Ppm)	Mean Amount Removed (Ppm)	Replicates
None	2.9	—	7	12.3	—	6	5.6	—	6
Water at 90 degrees F	2.6	0.3	4	13.9	-1.6	3	5.0	0.6	3
8.5 pounds A.C.*/270 gals at 90 degrees F	—	—	-	12.2	0.1	3	5.1	0.5	3
16 pounds A.C./270 gals at 90 degrees F	—	—	-	12.1	0.2	3	4.9	0.7	3
1 per cent Hydrochloric acid (HCl) at 90 degrees F	—	—	-	11.8	0.5	3	5.0	0.6	3
1 per cent HCl and 1 gal No. 27**/270 gals at 90 degrees F	—	—	-	11.1	1.2	3	5.1	0.5	3
1 per cent HCl and 2 gals No. 27/270 gals at 90 degrees F	—	—	-	12.0	0.3	3	5.3	0.3	3
2 pounds Red Apple wash†/270 gals at 90 degrees F	—	—	-	12.3	0.0	3	6.0	-0.4	3
2.75 pounds No. 30**/270 gallons at 90 degrees F	—	—	-	13.4	-1.1	3	5.1	0.5	3
5.25 pounds No. 30/270 gals at 90 degrees F	—	—	-	12.1	0.2	3	4.9	0.7	3
3.3 per cent Sodium hydroxide at 165 degrees F plus 3.3 per cent sodium hydroxide at 163 degrees F	—	—	-	9.6	2.7‡	6	4.4	1.2	6
1 per cent F-W-3 at 61 degrees F	2.5	0.4	5	—	—	-	—	—	-
1 per cent F-W-3 at 90 degrees F	2.2	0.7	3	—	—	-	—	—	-
1 per cent F-W-3 at 100 degrees F	2.3	0.6	3	—	—	-	—	—	-

*Product of DuBois Chemical Company.
**Product of Gamlen Chemical Company.
†Product of Van Waters and Rogers Company.
‡Significant at 5 per cent level.

The washing treatment with sodium silicate at 78 degrees F plus 1 per cent F–W–3 at 78 degrees F gave a significant residue removal in plot 5 but not in plot 6. The washing treatment of 50 pounds of sodium silicate at 90 degrees F plus 1 per cent F–W–3 at 78 degrees F gave higher results than the unwashed fruit in both plots 5 and 6. The washing treatment of 50 pounds of sodium silicate at 90 degrees F and 1 per cent F–W–3 at 90 degrees F did not remove a significant amount of DDT residue in plot 5 and gave a higher result in plot 6 than was obtained on the unwashed fruit.

None of the washing treatments (as shown in Table V) removed a

significant amount of DDT residue except the treatment of two baths of 3.3 per cent sodium hydroxide at 165 degrees and 163 degrees F in plot 9. There was no significant difference between treatments.

SUMMARY

1. Where spray programs recommended by the State College of Washington were followed, the DDT residue at harvest time on apples and pears was less than the present informal tolerance.
2. When additional sprays were applied (beyond the recommended number), or when sprays were applied late in the season, the DDT residue at harvest time was equal to or in excess of the present informal tolerance in 66.6 per cent of the samples analyzed.
3. The inclusion of light grade summer petroleum oil with DDT in the late summer sprays resulted in high DDT residue.
4. Late applications of 3 quarts of light grade summer petroleum oil alone increased the DDT residue remaining on the fruit at harvest time.
5. None of the washing treatments used effectively reduced high DDT residue.
6. Washing with relatively concentrated sodium hydroxide at higher temperatures failed to effectively remove the DDT residue.

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Factors Relating to the Effectiveness of 2,4-Dichlorophenoxyacetic Acid Sprays for Control of the Preharvest Drop of Winesap Apples

By ARTHUR H. THOMPSON and L. P. BATJER, *U. S. Department of Agriculture, Wenatchee, Wash.*

THE outstanding effectiveness of 2,4-dichlorophenoxyacetic acid sprays (hereafter referred to as 2,4-D) in retarding the preharvest drop of Stayman Winesap and Winesap apples has been reported by several investigators (1, 2, 3). Not only does 2,4-D, in comparison with naphthaleneacetic acid used for this purpose, have a greater intensity of effect, but a longer duration of effect as well. These advantages offer the possibility of applying this spray well in advance of the busy harvest season. In 1946, however, injury of varying degrees was evident in several experiments with all 2,4-D sprays applied by the writers during August, while no injury followed later applications of 2,4-D in the same experiment (2). This injury was evident 3 weeks after application of the spray as a premature yellowing of the foliage in the shaded portions of the trees. The following year many of these injured trees had a reduced crop, malformed fruits, and sparse, malformed foliage, very similar to that described by Marsh and Taylor (4). The present work was designed to obtain additional information on the various factors involved in the safe and effective use of 2,4-D for retarding fruit drop of the Winesap variety.

MATERIALS AND METHODS

The orchard in which this experiment was conducted was located in the immediate vicinity of Wenatchee, Washington. All sprays were applied with a standard portable power sprayer which developed 500 pounds pressure for two single-nozzle guns. The sodium salt of 2,4-D was adopted as the standard form for most of the treatments used, since in previous work this form was as effective in retarding drop as other forms tested, and also this compound seemed to be the least injurious (2). The sodium salt of 2,4-D (hereafter called the sodium salt), being very soluble, was dissolved in a small amount of water before it was added slowly to the water in the spray tank. For the one treatment in which the acid form of 2,4-D was used, this compound was dissolved in a small quantity of ethyl alcohol before it was added to the spray solution. In the three treatments in which oil was used as a spreader, 1 pint of a light emulsified oil was added per 100 gallons of water. In all other treatments, ¼ pound of a colloidal non-oil spreader was used per 100 gallons of water.

Each treatment was applied to 10 randomized Winesap apple trees, about 30 years of age, all bearing a moderate to heavy crop. Fruit drop records were taken at frequent intervals during the preharvest period, and immediately before and after each tree was picked. Harvest was delayed by rain for about 8 days beyond the normal commercial picking maturity for the Winesap variety in this orchard.

Results

The reduced concentration (5 ppm) of the sodium salt, applied early in August (Fig. 1), was effective in retarding drop only until October 3 to October 6, after which time this treatment showed a pronounced "running out". The standard strength spray (10 ppm) of the sodium salt, applied on the same day, was effective for a much longer period, but weakened considerably during the last 10 days prior to harvest. Both of these early applications, however, were significantly less effective than similar concentrations of the sodium salt applied on September 10. The standard strength spray of the sodium salt, applied on September 10, was the most effective treatment, resulting in a total cumulative drop of 3.1 per cent, in comparison with 7.6 per cent drop for the one-half strength spray applied on the same day. Naphthaleneacetic acid at 10 ppm, applied on September 26, was highly effective in retarding drop, but was not as effective as the September application of a similar concentration of the sodium salt of 2,4–D. Regardless of the time of application in this experiment, the 5 ppm concentration of the sodium salt was only about one-half as effective in controlling drop as was the 10 ppm concentration. The acid form of 2,4–D, used at 5 ppm, resulted in a fruit drop curve very similar to that of the 10 ppm concentration of the sodium salt spray applied at the same time. This suggests that the acid form might be more effective than the sodium salt form, though this was not indicated in previous work with these two materials (2). However, former comparisons between the two compounds were made at a concentration of 10 ppm.

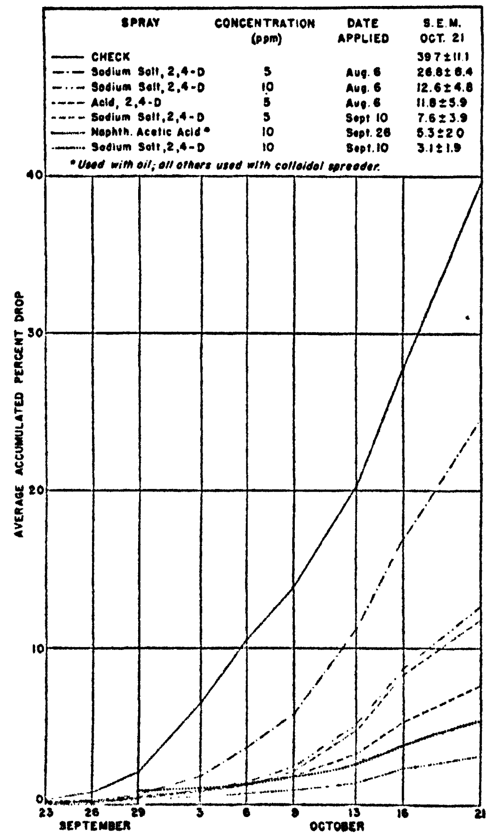

Fig. 1. Effect of hormone sprays on the preharvest drop of Winesap apples.

Several other treatments, not shown in Fig. 1, were included in this

experiment to determine the effectiveness of 2,4–D when applied in combination with various insecticides. A 5 ppm concentration of the sodium salt was included with each of three different materials (Xanthone, DN 111, and 0,O–diethyl O–p–nitrophenyl thiophosphate) being currently used or developed for mite control. These insecticides were used at the recommended rate for European mite and Pacific mite control, and were applied in combination with the sodium salt on August 6. These combination sprays resulted in essentially the same control of drop as the 5 ppm concentration of the sodium salt applied singly on that date.

The addition of oil to early August sprays containing 5 and 10 ppm of the sodium salt resulted in the same control of fruit drop as from sprays containing the same concentrations of the sodium salt, but used without oil. Thus in this experiment, addition of oil to the spray did not increase the effectiveness of the sodium salt.

No injury of the type previously noted (2) followed application of any of these treatments. However, in a near-by orchard in which 10 acres of Winesap trees were sprayed commercially on August 18 with the sodium salt at about 8 ppm, considerable injury resulted from the spray. On 12 trees that were marked for record purposes, a total accumulated drop of 0.7 per cent was recorded at harvest on October 9. For 10 trees in an adjacent row that were sprayed with naphthaleneacetic acid (airplane application, 2400 ppm) on September 27, a total accumulated drop of 6.6 per cent was obtained.

A noticeable difference between sprayed and unsprayed trees in the amount of fruit knocked off or dropped by pickers during harvest has been mentioned (2). In the experiment summarized in Fig. 1, a careful record was made of "knock-offs" from each of the 124 trees involved. All trees, irrespective of treatment, were classified into seven groups based on the amount of preharvest drop. The mean drop of these groups ranged from 1.5 per cent to 45 per cent. The amount of fruit knocked off or dropped during picking was averaged for each group, and is presented graphically in Fig. 2. It will be noted that there is virtually a straight-line relationship between preharvest drop and "knock-offs". On trees that had dropped an average of about 40 per cent by harvese time, the pickers knocked off 10 to 11 per cent of the fruit, whereas on those trees for which drop had not exceeded 5 per cent by harvest time, the "knock-off" was only 3 to 4 per cent.

Discussion

Earlier work (2) showed no significant difference in retarding fruit drop between 5 and 10 ppm of the acid form of 2,4–D applied in September. This suggested the possibility of using a reduced concentration in August sprays to avoid possible injury. However, the data presented here show that 10 ppm of the sodium salt was much more effective than the 5 ppm concentration, regardless of whether the spray was applied in August or September. The addition of oil to sprays applied during August failed to increase their effectiveness.

The relationship of effectiveness of preharvest sprays to amount of fruit knocked off during picking is rather striking. These data emphasize that the effective use of hormone sprays, aside from retarding fruit drop prior to harvest, greatly reduces losses during the picking operation.

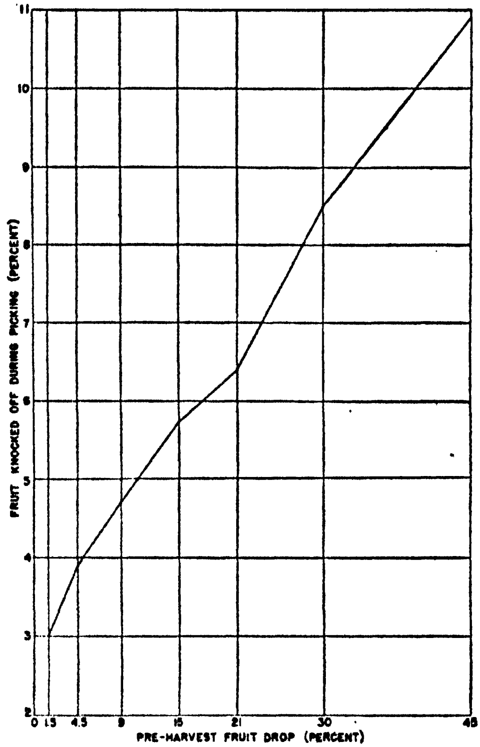

Fig. 2. Relationship between the amount of fruit knocked off during picking and the amount of fruit drop prior to harvest.

The greater effectiveness of the September sprays in comparison with those applied in August is in direct contradiction to previous results reported by the writers (2). A probable explanation of this difference is the failure of any of the August treatments in the present experiment to result in injury. In previous experiments, treatments applied during August have resulted in a very high degree of effectiveness, but have been invariably associated with varying degrees of injury to foliage and buds. Failure of injury to develop from the August treatments in the work reported here was likely due to differences in seasonal conditions that limited the amount of 2,4–D absorbed by the tissues. If this assumption is correct, it possibly explains the failure of the early sprays to reduce drop as effectively as former treatments applied during August. In the case of the commercial spraying cited above (applied August 18), injury in the shaded portion of the trees was very evident at harvest time, and fruit drop reached a cumulative total of only 0.7 per cent. The trees in this orchard had not been pruned the preceding year. The resulting dense character of growth afforded little penetration of light to the inner portions of the tree. Repeated observations by the writers have indicated a higher incidence of injury from 2,4–D sprays applied to trees of this type in comparison with more open trees supporting vigorous wood throughout the entire structure. In the experiment reported here, the trees were of the open type; and while no injury resulted when the sprays were applied in early August, neither was satisfactory control of fruit drop obtained. This evidence indicates a narrower latitude in timing of the spray than was

formerly supposed. From the commercial standpoint, therefore, it would seem that 2,4–D sprays, to be used safely and effectively under Northwest conditions, should be applied at a concentration of 10 ppm during September — approximately 3 weeks in advance of anticipated drop, or 5 to 6 weeks prior to the conclusion of harvest. Such a procedure in the present studies, as well as in previous experiments (1, 2), has afforded good control of preharvest drop with complete freedom from any type of injury.

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Retardation of Ripening of Fruits with the Methyl Ester of Naphthalene Acetic Acid[1]

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SOME preliminary tests with peaches and Bartlett pears during the early fall indicated that rate of ripening of these fruits might be retarded substantially by wrapping the individual fruits in paper impregnated with the methyl ester of naphthalene acetic acid and then packing the fruits in rather tightly-closed cardboard containers. At that time, the season was too far advanced to permit further tests with these fruits, so plans were made to determine what effect the methyl ester might have on ripening rates of several varieties of apples.

RESPIRATION

Approximately 1.5 kilograms of Grimes apples were wrapped individually in oiled apple wraps to which had been applied an atomized spray of methyl ester of 1000 ppm concentration. A lot of apples of similar weight was wrapped in oiled-impregnated paper as a control. Each lot was sealed in desiccators on November 3 and respiration rates measured at an average of 69 degrees F in the static system described by Haller and Rose (1). During a period of 84 hours, the average respiration rates in terms of milligrams of CO_2 evolved per kilowatt-hour were 27.6 and 28.3, respectively, for the treated and untreated fruits, indicating a reduction of approximately 2.5 per cent for the treated apples.

Similar quantities of Jonathan apples were subjected to the same treatments on November 11, and respiration rates determined for the greater portions of each of 3 days (67 hours). In this case, the apples treated with the methyl ester gave a slightly higher rate of respiration; 27.2 versus 26.4 milligrams CO_2 per kilowatt-hour.

The methyl ester was then incorporated with a 10 per cent geon 31X solution at a concentration of 1000 ppm of the ester and this mixture was atomized on McIntosh fruits designated as treated. The untreated lot received neither geon nor methyl ester. Respiration rates for these two lots of McIntosh apples were obtained from November 14 to November 24. Respiration rates for both lots of apples were depressed each successive day after the fourth day. The amount of CO_2 evolution for the treated apples was rather consistently less than that for the controls, the averages for the period being 24.2 milligrams per kilowatt-hour for the treated and 27.0 for the control. In this case, the combination of geon and methyl ester reduced CO_2 evolution 10.37 per cent.

Inasmuch as a combination of geon and methyl ester was applied to the above lot designated as treated, it seemed desirable to apply geon to both lots of McIntosh in the next determination in an effort to measure the effects of the methyl ester on respiration rates. Thus, the

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untreated received an application of 10 per cent geon and the treated lot was atomized with the geon plus 1000 ppm of the methyl ester. These two lots were treated November 25 and respiration rates were measured for each of seven successive days (166 hours). The quantities of CO_2 evolved were 27.1 and 28.2 milligrams per kilowatt-hour, respectively, for treated and untreated lots, an average depression of approximately 39 per cent, possibly due to the incorporation of the methyl ester in the geon.

Another test with McIntosh was started December 5 and continued for 7 days. In this case the concentration of methyl ester was increased to 10,000 ppm. During this test, the rate of CO_2 evolution for the control lot (geon alone) exceeded that for the geon plus methyl ester during the first 2 days, and then the treated apples evolved substantially more CO_2 than the controls. The average quantities of CO_2 evolved were 25.0 and 23.3 milligrams per kilowatt-hour, respectively, for the treated and untreated lots. However, when the apples were removed from the desiccators at the end of the experiment, four of those receiving the high concentration of methyl ester in the geon were badly scalded, indicating that the injury caused by the high concentration of methyl ester served to accelerate the respiration rate.

On December 12, approximately 1.7 kilograms of Northern Spy apples received an application of 10 per cent geon solution and a second lot of similar quantity was atomized with 10 per cent geon plus methyl ester at the rate of 3,000 ppm of the ester. The average amounts of CO_2 evolved per kilowatt-hour for the 8-day period of the test were 22.7 and 21.3 milligrams, respectively, for the geon alone and the geon plus methyl ester of naphthalene acetic acid.

In general, methyl ester of naphthalene acetic acid incorporated in either paper wraps or geon has rather consistently retarded respiration rates of apples at certain concentrations. It is possible that certain concentrations not attempted in these tests may give more desirable results. Furthermore, it is also possible that this material may have further retarding effects with certain other fruits that have substantially high rates of respiration. Then there is the possibility of finding a more suitable carrier for the methyl ester.

Holding in Open Containers

Wealthy, McIntosh, and Delicious apples and Bartlett and Bosc pears were wrapped individually in oiled apple wraps and in similar wraps that were also impregnated with the methyl ester of naphthalene acetic acid at a concentration of 1,000 ppm and held in slatted crates at both 33 degrees F and room temperature for approximately 65 days. Pressure test readings and observations made periodically indicated no significant differences in rates of ripening that could be attributed to the use of the methyl ester. It is possible, however, that tight containers that would retard diffusion of the ester into the storage room atmosphere might give a response different from that recorded.

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Some Factors Affecting Ascorbic Acid Content of Apples[1]

By A. E. Murneek and S. H. Wittwer, *University of Missouri, Columbia, Mo.*

Compilations of the existing records on ascorbic acid content of apples show wide variations not only as between varieties (1, 2) but also within the variety (2). Undoubtedly several factors, other than the genetic constitution of the plant, affect the production and concentration of this highly labile vitamin in the apple and many other fruits. Some of these factors seem to be operative in the orchard, while the fruit is developing and maturing, still others have a bearing during the post harvesting or the storage periods. The present investigation was undertaken with the object of securing more information on the subject, which might help to clarify to some extent the situation.

Material and Methods

The apples used for this study came from standard trees growing under sod culture in the experimental orchard of the University of Missouri. Unless otherwise stated, all fruit was secured in what was considered a commercially desirable stage of maturity. They were harvested with care early in the forenoon, brought to the laboratory and used on the same day for ascorbic acid assays, excepting of course, when storage tests were made. For the study of seasonal changes fruit of various stages of maturity were obtained at weekly intervals extending over a considerable period as indicated in Tables I and II. Usually more fruit was picked than was necessary. This permitted a careful selection of specimens of the various groups for size, amount of color development and freedom from blemishes.

As a rule eight well matched apples constituted a sample. They were quartered and a thin slice, cut toward the core, was made from each segment, or a total of 32 sections. These included the skin, cortical tissue, some of the pith, but no core. The material, amounting to 200 grams in each case, was macerated in a Waring blendor for exactly 3 minutes and submitted immediately to analysis by means of the 4,6–dichlorophenolindophenol dye reduction procedure (3). The ascorbic acid concentration is expressed in milligrams per 100 grams of fresh material.

Results

Changes in ascorbic acid content of five fall and two summer varieties of apples were determined beginning from the "hard ripe" stage, as indicated by pressure tests and number of days from flowering, and extending to full maturity. The results are presented in Tables I and II.

It will be observed that in all the fall varieties tested, excepting Winesap, there was a gradual and quite consistent increase in ascorbic acid concentration as the fruit matured, followed by a decrease. The reduction, with increasing maturity in some varieties, like Jonathan

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TABLE I—ASCORBIC ACID CONTENT OF APPLES WHILE MATURING ON TREES (FALL VARIETIES) (MILLIGRAMS PER 100 GRAMS OF CORED BUT NOT PARED FRUIT)

Variety—	Jonathan	Delicious	Golden Delicious	Rome	Winesap
Date of picking:					
Aug 26	7.50	—	—	—	—
Sep 2	7.00	8.00	—	—	—
Sep 9	7.00	8.00	7.75	7.00	—
Sep 16	8.16	9.60	7.68	7.20	—
Sep 23	8.16	9.60	8.64	7.20	13.90
Sep 30	7.69	8.64	8.50	7.69	12.62
Oct 7	—	8.00	8.50	8.00	11.00
Oct 14	—	—	8.50	7.20	11.50
Oct 21	—	—	—	6.72	11.28
Oct 28	—	—	—	—	9.60

TABLE II—ASCORBIC ACID CONTENT OF APPLES WHILE MATURING ON TREES AND AFTER A BRIEF PERIOD IN COMMON STORAGE—70 TO 80 DEGREES F (SUMMER VARIETIES) (MILLIGRAMS PER 100 GRAMS OF CORED BUT NOT PARED FRUIT)

Variety—	Yellow Transparent		Duchess	
	a*	b†	a	b
Date of picking:				
Jul 1	11.16	7.08	—	—
Jul 8	8.13	6.97	13.02	8.24
Jul 15	8.85	2.36	8.85	5.31
Jul 22	6.49	—	8.85	4.72
Jul 29	—	—	5.90	4.13

*Immediately.
†After 6 days in common storage.

and Golden Delicious, was small, while in others, like Delicious and Rome, it was considerable. As regards changes in content of this vitamin, the Winesap variety behaved like the summer varieties, Yellow Transparent and Duchess, showing a fairly consistent and marked decrease from the hard ripe to the mature stages.

An interesting and important feature in the two summer apples was the very rapid reduction in ascorbic acid after a relatively brief, 6-day period in common storage (Table II). This occurred also in similar storage with fall varieties of apples. Records presented in Table III show that after an 8-day period in common storage there was a conspicuous decrease in ascorbic acid concentration in three out of the

TABLE III—ASCORBIC ACID CONTENT OF FALL APPLES AFTER A BRIEF PERIOD IN COMMON STORAGE—70 TO 75 DEGREES F (MILLIGRAMS PER 100 GRAMS OF CORED BUT NOT PARED FRUIT)

Variety	Harvest Date: Oct 7	After Storage: Oct 15
Golden Delicious	8.50	5.76
Delicious	8.00	5.28
Rome	8.00	4.80
Winesap	11.00	10.05
	Harvest Date: Oct 14	After Storage: Oct 18
Golden Delicious	8.70	8.16
Rome	7.20	5.32
Winesap	11.50	11.05

four varieties tested and to a lesser extent in Winesap, a variety that is known to ripen slowly. Even during as brief a period in storage as 4 days, at relatively high temperature (70 to 75 degrees F) there may result a significant ascorbic acid depression in some varieties, such as the Rome. The rapid loss of this vitamin, possibly due to oxidation, during a few days of handling, transportation or keeping may account, in part at least, for the considerable variability in results of assays as recorded in literature. But there seem to be other factors in operation that may at times be responsible for discrepancies in results in ascorbic acid assays.

The data presented in Table IV show that the concentration of this vitamin may vary to some extent with the size of the crop, both as between trees and limbs of the same tree. When the crop is light, then the ascorbic acid concentration in the fruit is apt to be relatively high. But, in addition, there are even greater differences in this vitamin in apples produced on outside and inside branches of the same tree (Table V).[2] This is true whether a tree bears a light, moderate or a

TABLE IV—ASCORBIC ACID CONTENT OF FRUIT ON COMPARABLE TREES OR LIMBS WITH A LIGHT OR A HEAVY CROP (MILLIGRAMS PER 100 GRAMS)

Variety and Condition of Trees or Limbs	Light Crop	Heavy Crop
Jonathan, old trees	6.25	4.27
York, limbs on old tree	7.63	6.25
Jonathan, limbs on young trees	4.06	3.65
Winesap, limbs on old trees	11.75	11.00

TABLE V—ASCORBIC ACID CONTENT OF APPLES GROWN ON OUTSIDE AND INSIDE BRANCHES OF THE SAME TREES (MILLIGRAMS PER 100 GRAMS)

Variety and Condition of Tree	On Outside Branches	On Inside Branches
Jonathan, old tree, moderate crop	6.25	4.75
Golden Delicious, old tree, light crop	6.37	5.94
Golden Delicious, heavy crop	7.20	6.25
Golden Delicious, light crop	8.40	5.76
York, heavy crop	7.63	5.25
Stayman, heavy crop	7.25	5.88
Winesap, old tree	10.63	8.25
Winesap, moderate crop	11.52	10.05
Rome, light crop	6.72	5.28
Rome, light crop, large fruit	4.50	4.25
Rome, light crop, small fruit	5.56	4.90

heavy crop and to a slight extent also independent of the size of the fruit (Rome). In general, however, and considering all exposures, the smaller apples, with the same access to light (same color) are higher in ascorbic acid than larger ones of the same variety (Table VI). When bearing equivalent crops, weak trees, as judged by amount of shoot growth and character of foliage, seem to produce apples of higher ascorbic acid value than vigorous trees (Table VII).

Undoubtedly most of the above referred differences are due to light effects. Literature is replete with references to the influence of light on the production of this vitamin. Far more of it seems to be concen-

[2]Similar differences were found in Elberta peaches: Mgs/100 grams ascorbic acid: fruit from inside branches 5.5, outside branches 7.6.

TABLE VI—Ascorbic Acid Content of Small and Large Apples From the Same Trees (Milligrams Per 100 Grams)

Variety and Condition of Tree and Fruit	Small	Large
Rome, old tree	7.20	6.72
Rome, outside fruit	5.56	4.50
Rome, inside fruit	4.90	4.25
Winesap, old tree	11.00	10.05
Jonathan, young tree	4.69	3.65

TABLE VII—Ascorbic Acid Content of Fruit From Weak and Vigorous Trees of Comparable Age (Milligrams Per 100 Grams)

Variety and Condition of Tree	Weak Tree	Vigorous Tree
Golden Delicious, light crops	7.50	6.25
Jonathan, young trees	6.31	4.13

trated in the skin than in the pulp of fruits (4, 5, 6, 8) and more in the pulp near the epidermis than the area close to the core (4, 7). Small fruit, because of a larger skin to pulp ratio may be expected to contain relatively more ascorbic acid than larger specimens (5).

Considerable differences were found to exist between the shaded and exposed (to direct light) halves of the apple, as is evident from records presented in Table VIII. This seems to be true not only in

TABLE VIII—Ascorbic Acid Content of Exposed (to Direct Light) and Shaded Halves of the Same Apples (Milligrams Per 100 Grams)

Variety and Condition of Tree and Fruit	Exposed Half	Shaded Half
Stayman, old tree, outside fruit	9.13	7.00
Stayman, old tree, outside fruit—peeled	6.38	5.19
York, old tree, outside fruit	8.50	5.75
York, old tree, outside fruit—peeled	6.13	5.25
Winesap, old tree, outside fruit	11.15	9.50
Winesap, old tree, inside fruit	8.88	8.38
Golden Delicious, young tree	3.75	3.13

TABLE IX—Effect of Heavy Nitrogen Fertilization on Ascorbic Acid Content of Apples (Milligrams Per 100 Grams)

	Average N Fertilization	Very Heavy N Fertilization
Rome, highly colored fruit	6.87	4.68
Rome, fruit of average color	5.63	4.56

cases of highly colored fruit, such as Winesap, but also in less pigmented varieties (York and Stayman) or in ones without red color, such as Golden Delicious.[8] Even when the skin is pared off there were found significant differences in this respect, which is in agreement with some previous observations (9).

The relative amount of soil nitrogen supply, too, seems to have a bearing on ascorbic acid content of apples. Fruit of equal size and exposure to light were obtained from Rome trees some of which had received for several years usual amounts of commercial nitrogen fer-

[8]Elberta peaches also: Mgs/100 grams: "Red" side 8.0, "Green" side 6.3.

tilizers while others had been given heavy (x 3 usual) quantities. Results of ascorbic acid assays of these two groups of fruit are given in Table IX. Whether highly colored or fruit of average amount of red color were selected from trees of the two contrasting groups, as regards nitrogen fertilization, very heavy N applications evidently reduced ascorbic acid concentration in apples. This is in accord with the results obtained by other investigators with apples (10, 11) and with peaches (12).

Summary

The presented experimental evidence shows quite clearly that in assays of ascorbic acid concentration in apples, and probably most other fruits (13), careful consideration must be given to the various factors affecting the production of this vitamin. Varietal differences certainly exist. Summer varieties have a higher ascorbic acid content than most winter varieties when harvested in what are considered "green" or "hard ripe" stages of maturity. In this respect the Winesap apparently is an exception, as are a few other late keeping varieties. It seems to behave like a typical summer apple. Seasonal differences may be considerable in all varieties, depending on the stage of maturity and speed of ripening of the fruit. Those very high early in the season (summer apples) may be as low or even lower than winter sorts in ascorbic acid concentration if harvested late.

Storing even for a brief period, at relatively high temperature (common storage), evidently results in considerable decrease in ascorbic acid content, hence handling of the fruit after picking must be with dispatch and assays should be made promptly.

The condition of the tree, the nitrogen supply, the size of the crop, the size of the fruit and their exposure to light, are some of the other important factors that have a considerable bearing on the ascorbic acid value of apples and probably other fruits. Of these light seems to be of major importance in the production and concentration of this vitamin.

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Carbon Dioxide Production of Deciduous Fruits Held at Different Oxygen Levels During Transit Periods

By L. L. Claypool and F. W. Allen, *University of California, Davis, Calif.*

Most studies on respiration of fruit under transit or storage conditions have been made with reference to maturity, temperature, or where the surrounding atmosphere had been modified by the addition or accumulation of carbon dioxide. The influence of oxygen alone at levels below and above that in air has received relatively little attention. Recently Kidd and West (7) reported experiments made with the Bramley's Seedling apple in 1925, in which they found the respiration climacteric was hastened and that for a number of weeks the respiration rate was markedly increased by oxygen at high levels. Five and also 10 per cent oxygen had the opposite effect. Parija (8) in 1928 also working with apples secured minimum respiration in 5 per cent oxygen but with a rise in respiration rate both below and above this concentration. Biale (3), holding avocado fruits in different oxygen concentrations, found that the respiration rate was markedly reduced by low concentrations and that the climacteric peak was delayed and suppressed in magnitude. Oxygen levels higher than that of air resulted in some increase of the respiration rate which Biale considered as not significant. His respiration studies at high oxygen levels were apparently limited to a single experiment.

With lemons, Biale and Young (4) found that oxygen above that in air accelerated respiration somewhat in proportion to the oxygen level. Oxygen below that of air retarded respiration but there was a threshold level below and above which CO_2 production increased.

Limited observations on the general effects of low oxygen in retarding the ripening of Bartlett pears and of Yellow Newtown apples have been made and previously reported upon by Allen (1, 2). Oxygen values below that of air had a retarding effect upon coloring and softening of both fruits. These differences, however, were not so marked as where such atmosphere contained 5 to 10 per cent of CO_2.

Procedure

During 1946 simulated transit tests were made on several fruit species, where the atmosphere in which fruits were held was varied in its oxygen content. Cherries, apricots, plums, peaches, pears and grapes were held under 2½, 5, 10, 15 and 21 per cent (air) oxygen, and in addition cherries and apricots were held also in 30, 50, 75 and 100 per cent oxygen. Tests were usually made at two temperatures, 40 or 45 degrees F to represent refrigerator car temperatures and 65 degrees F. All test lots were kept in the differential treatments for 10 days after which fruits were removed to air at 65 degrees F. Cherries at 40 degrees F were an exception to this, being held 13 days in the differential treatments.

Gas mixtures of desired composition were passed continuously over the fruit, being introduced into the bottom of a 3,500 cc wide-mouth

jar by means of a rubber tube connected to a copper tube through the lid, and removed through a second copper tube in the lid. The rate of flow at 65 degrees F was maintained at about 100 cc per minute and at 40 to 45 degrees F about 50 cc per minute, giving a change of air in the container calculated on the basis of free air space about every 20 and 40 minutes respectively. The desired gas compositions and flow rates were secured by mixing air with nitrogen or oxygen through flowmeters of the type described by Claypool and Keefer (6).

Respiration measurements were made daily during the time fruits were in the differential treatments. The colorimetric method was used for all CO_2 determinations (6). Bromthymol blue indicator of 0.0005 per cent concentration buffered with sodium bicarbonate of 0.001 N concentration was used for all tests. The gases coming from the jars containing test fruits were bubbled through 10 to 15 cc of indicator solution using glass capillary tubes to give uniform bubbling and to prevent contamination of the indicator solution by the rubber tubing. After a minimum of 10 minutes the colorimeter tubes containing the indicator were removed from the air stream and stoppered. Light transmission readings were made with an Evelyn colorimeter using a 620 mu filter. Having thus measured, indirectly, the per cent CO_2 in the atmosphere coming from the fruits, and knowing the rate of air flow and the weight of fruit, determination of the respiration rate becomes a simple calculation. This method is very rapid in comparison to methods where CO_2 is collected. The air was not scrubbed of CO_2 prior to passing over the fruit but a blank was always run to determine the CO_2 originally present in the air.

Following removal from modified atmospheres the appearance, condition, and dessert quality of the fruits were determined. Records were kept until each lot had reached a state where it was considered no longer commercially salable.

Results

Part of the data collected in this experiment was reported in a previous paper (5) referring to the use of modified atmospheres in the transportation of deciduous fruits. Plums, pears and peaches held in an atmosphere containing 2½ per cent oxygen, and plums, pears and grapes held in an atmosphere containing 25 per cent CO_2 were found, following a 10-day period at 65 degrees F, to be in a good marketable condition equal to that of fruits held at 40 degrees F either in air or modified atmospheres. Data referring to the respiration of fruits held in the oxygen series are reported here.

Cherry:—The variety of cherry used is not known, although it was quite similar to Bing in season, size and firmness. Respiration curves are not shown for lots held at 65 degrees F because of decay that developed during the holding period. Respiration readings taken during the first 5 days before decay was observed showed the 2½ per cent and 5 per cent oxygen lots to have respiration rates of about 60 per cent and 85 per cent respectively of that of the air lot. Ten and 15 per cent O_2 lots were essentially the same as the air lot. High oxygen lots were quite similar in respiration to the air lot. If any differ-

ences existed, the 75 and 100 per cent oxygen lots changed color slightly less than the middle oxygen and air lots.

At 40 degrees F, Fig. 1, approximately the same relationship existed between the O_2 level and the respiration rate as occurred at 65 degrees F. Two and one-half and 5 per cent O_2 definitely depressed the

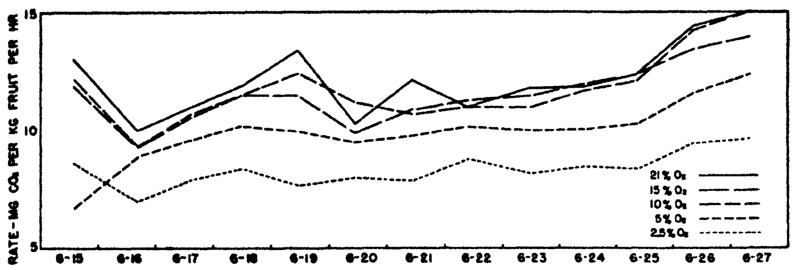

FIG. 1. Respiration rates of cherries at different oxygen levels at 40 degrees F.

metabolic activity of the fruit as measured by CO_2 production, and retarded color change. The respiration rates of lots of cherries held in 30, 50, 75 and 100 per cent oxygen were similar to that of the air lot. At the end of the transit period these fruits also were of similar color, having changed from a light to a medium red.

No abnormal flavors were evident in any lot either at 65 degrees F or 40 degrees F.

Apricot:—Royal apricots harvested June 27 were yellowish green, approximating the most advanced maturity that would be shipped to eastern markets. Duplicate lots of 1000 grams, each containing 28 fruits were placed in differential treatments the same day as harvested.

At 65 degrees F the tests were terminated after 8 days as most fruits were full ripe and becoming soft. At oxygen levels below that in air the respiration rates were decreased nearly in proportion to the O_2 supplied (Fig. 2), at oxygen levels above that in air there was no increase in respiration rate or any consistent differences between any of the lots and air (Fig. 3). The 2½ per cent O_2 lot was the greenest of any at the end of 8 days followed by the 5 per cent lot. No other differences in ripeness were evident except that the fruit in 100 per cent O_2 appeared slightly less ripe than all but the 2½ and 5 per cent O_2 lots. There were no abnormal flavors in any fruit, but the fruit held in 2½ per cent oxygen seemed somewhat flat and lacking in true apricot flavor. The fruit in these treatments did not reach the climacteric during differential treatments, but it will be noted that the respiration rate seemed to be near the peak as indicated by the leveling off of some of the curves.

At 40 degrees F the curves showing the respiration rates at O_2 levels below that in air are well spread and respiration was again proportional to the oxygen content of the atmosphere (Fig. 4). At this temperature the respiration curves drifted downward for the first 4 days, subsequently showing only a slight indication of a climacteric rise, which is due to the limited period of the test, and is probably not

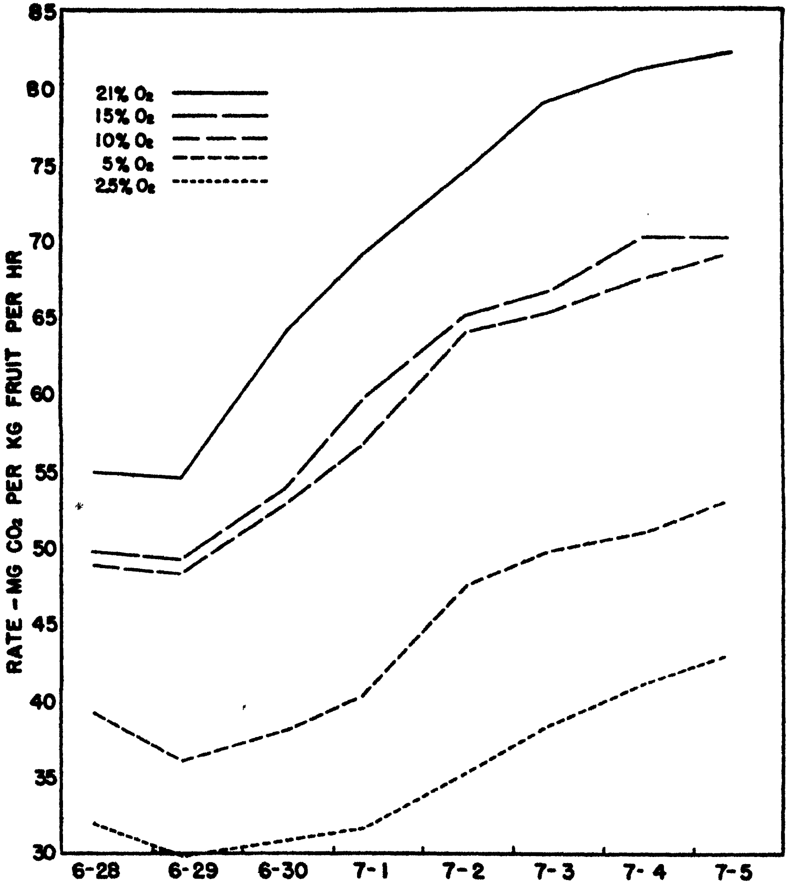

FIG. 2. Respiration rates on Royal apricots at oxygen levels of 2½ to 21 per cent at 65 degrees F.

significant. Oxygen levels above 21 per cent (Fig. 5) again failed to cause an increase in the respiration rate. In fact, except for the first 2 days, the 75 and 100 per cent O_2 lots respired slightly less rapidly than the fruit in air and quite similar to the 15 per cent O_2 lot. In general, however, the respiration of all lots was similar as shown by the close proximity of the different curves. These also had a downward trend for the first 4 days after which they remained level.

Not withstanding the great differences in respiration rate between fruit held in air and either in a reduced or an increased oxygen atmosphere, a comparison of ripeness and condition following the 10-day transit period showed little effect of oxygen level on these fruit changes.

Plum:—Santa Rosa plums, harvested July 9, were divided into lots of 20 fruits, each lot weighing about 1180 grams. Duplicate lots were

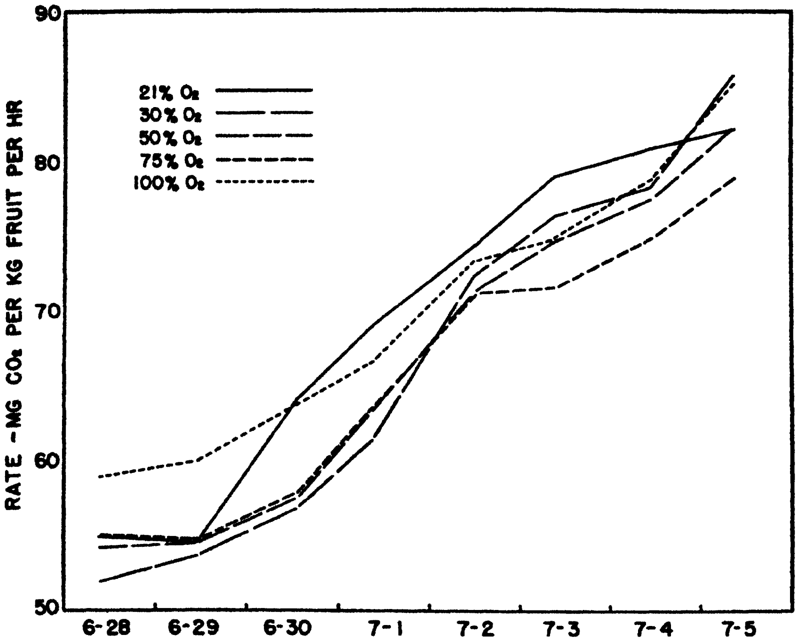

FIG. 3. Respiration rates on Royal apricots at oxygen levels of 21 to 100 per cent at 65 degrees F.

set up for each treatment. Surface color at harvest time averaged between 75 and 100 per cent light red.

At 65 degrees F the respiration curves (Fig. 6) were widely spread with the divergence increasing with time. The 10, 15, and 21 per cent oxygen lots displayed marked increases in their respiration rates as they approached the climacteric. The fruit in 5 per cent oxygen showed only a slight increase in rate, while that in 2½ per cent oxygen showed a consistent reduction. Following the 10-day period of treatment the fruit held in 2.5 per cent O_2 had changed color only slightly, approaching a full light red, whereas the air lot had attained a color about three shades darker, listed as intermediate between medium dark and dark red. Fruits of this latter color while of good dessert quality are too ripe to be passed through normal sales channels. The 5 per cent O_2 fruits were less advanced in color than the air lots but were also too ripe for the market.

At 40 degrees F differences in respiration rate (Fig. 7) were also quite marked. However, at this relatively low temperature, color changes were slight during the simulated transit period and hence, when the different samples were removed for ripening all were of similar appearance. Furthermore, as ripening progressed no differences developed. It is interesting to note that the 2½ per cent oxygen lots at 65 degrees F and at 40 degrees F were similar in color at the end of the transit period and ripened at the same rate following re-

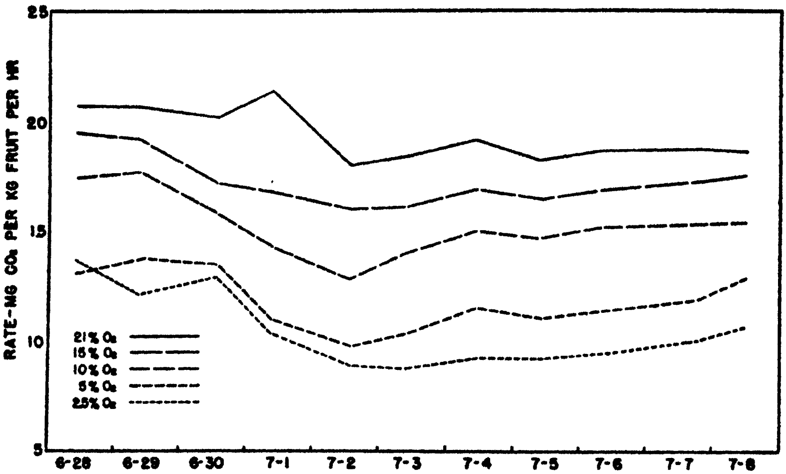

FIG. 4. Respiration rates on Royal apricots at oxygen levels of 2½ to 21 per cent at 40 degrees F.

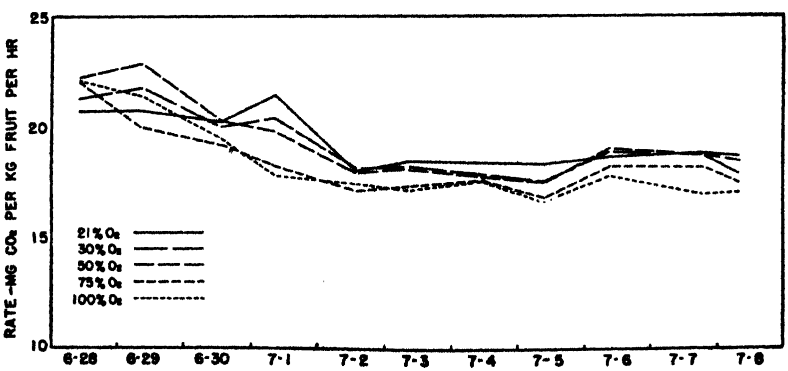

FIG. 5. Respiration rates on Royal apricots at oxygen levels of 21 to 100 per cent at 40 degrees F.

moval to air at 65 degrees F. Flavor was normal in all lots at both temperatures.

Peach:—The Primrose peach used in these experiments is a good flavored, firm fleshed, freestone peach slightly earlier than Elberta. Fruits were harvested at a stage where they were well filled out, greenish yellow in color and several days from a tree ripe stage.

At 65 degrees F the respiration curves were rather similar to those of the Santa Rosa plums. Differences in respiration rate at the various oxygen levels increased with time and there was a wide spread in the curves somewhat proportional to the per cent oxygen in the atmosphere (Fig. 8). At the end of the 10-day period the air and 15 per cent O_2 lots seem to be nearing the climacteric and had reached full color and ripeness. At this time the fruit held in 2½ per cent O_2 had in-

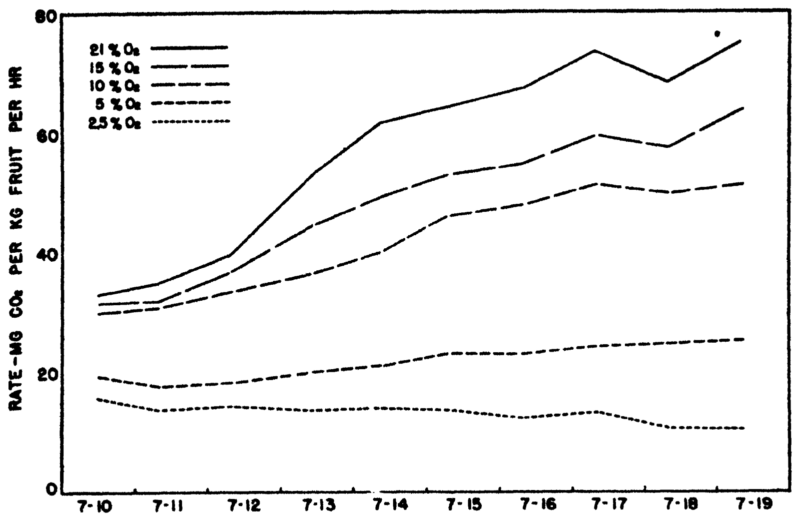

FIG. 6. Respiration rates of Santa Rosa plums at different oxygen levels at 65 degrees F.

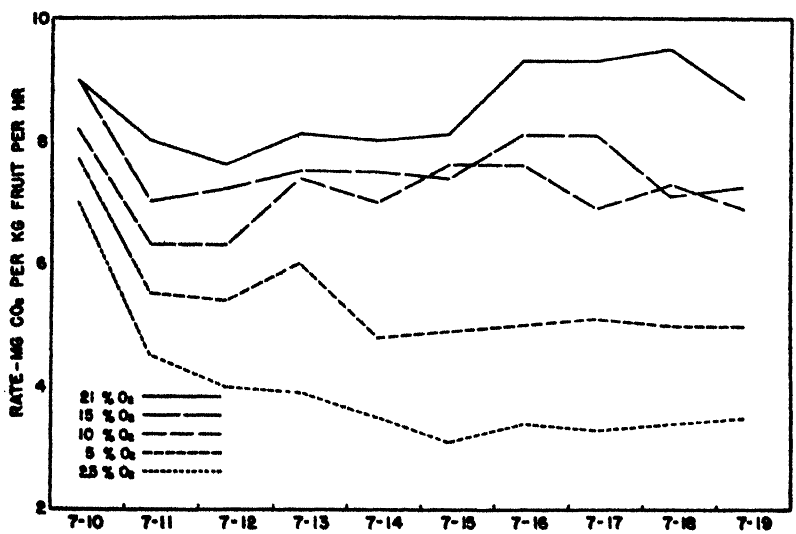

FIG. 7. Respiration rates of Santa Rosa plums at different oxygen levels at 40 degrees F.

creased only slightly in respiration rate and had exhibited almost no color change. The 5 and 10 per cent O_2 lots were intermediate between the fruit held in 2½ per cent oxygen and that in air. There was no harmful effect on flavor resulting from any treatment.

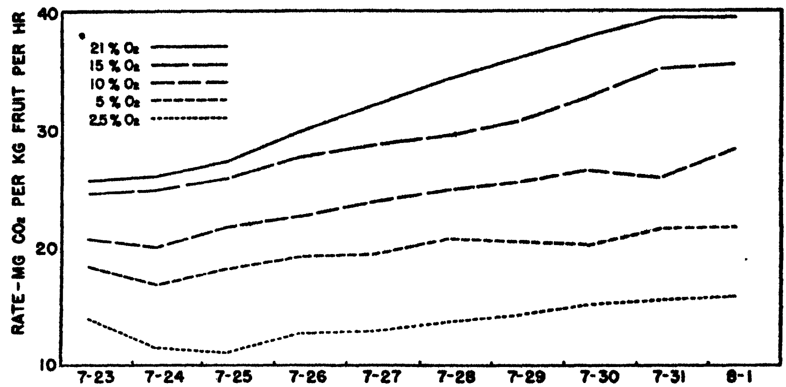

FIG. 8. Respiration rates of Primrose peaches at different oxygen levels at 65 degrees F.

At 40 degrees F (Fig. 9) there was a general downward trend of the respiration curves similar to those of the apricots at this temperature, except in the 2.5 per cent O_2 lot which remained very low throughout the experiment. The wide differences in respiration rates at the beginning of the experiment became continuously less until at the end of 10 days the spread was no more than half the original amount. However, at this time there was no significant difference in the color of any of the 40 degrees F lots.

Here again, fruits held in 2½ per cent oxygen at 65 degrees F for 10 days had no more color development than those held at different oxygen levels at 40 degrees F.

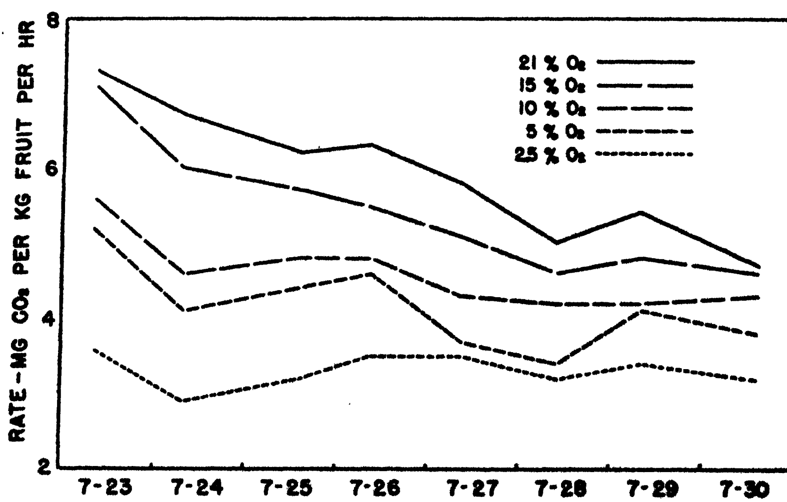

FIG. 9. Respiration rates of Primrose peaches at different oxygen levels at 40 degrees F.

Pear:—Bartlett pears having a pressure test of 18½ pounds at harvest on August 5 showed somewhat the same trends in respiration rate as the stone fruits, (Fig. 10). Only the results secured at 65 degrees F are shown here due to difficulty during this period with the temperature controls in the 40 degrees F room, which resulted in fluctuating temperatures and corresponding fluctuating respiration rates.

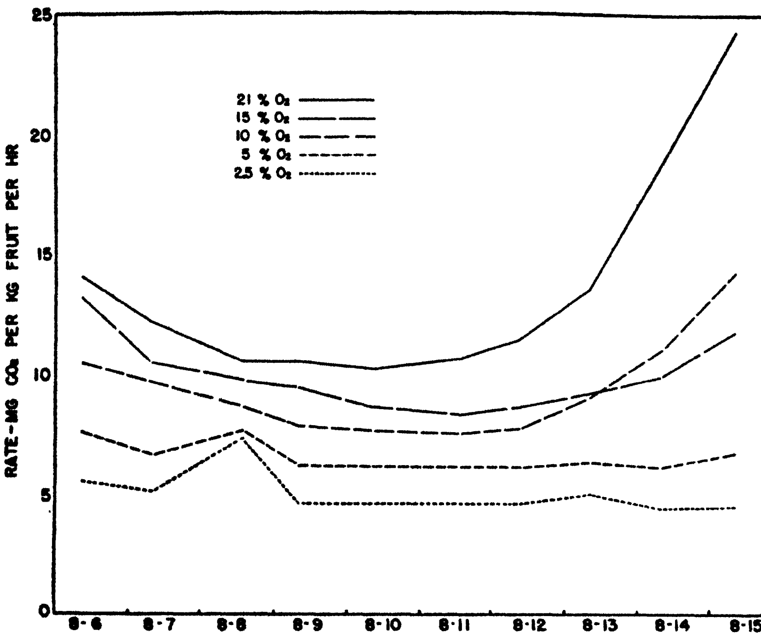

Fig. 10. Respiration rates of Bartlett pears at different oxygen levels at 65 degrees F.

The climacteric rise of Bartlett pears is more abrupt than that of stone fruits. It will be noted that the three higher oxygen lots were in the climacteric rise at the end of the transit period, but that the 2½ and 5 per cent O_2 lots showed no indication of reaching this stage. This is further borne out by the fact that the higher oxygen lots were in various stages of change from greenish-yellow to yellow, whereas the two low oxygen lots were still light green in color and about the same as the various lots of fruit held at 40 degrees F. Following removal to air at 65 degrees F for ripening there was some indication that the fruit held in low oxygen developed better flavor than the others.

Grape:—Tests were made on both Thompson Seedless and Tokay grapes but respiration measurements were made only on the former. These tests were made at 65 degrees F only, but the test lots were compared with grapes held for the same period at 45 degrees F in air. Here again the oxygen level had a marked influence on respiration

rate. The respiration curves (Fig. 11) maintained an approximate level condition during the 10-day period, except for the 2½ and 5 per cent oxygen lots, which exhibited a downward trend the first few days before leveling off. There was no indication of a climacteric rise even in the air lot, indicating the likelihood that grapes are post climacteric at the normal harvest maturity. Unlike the other fruits

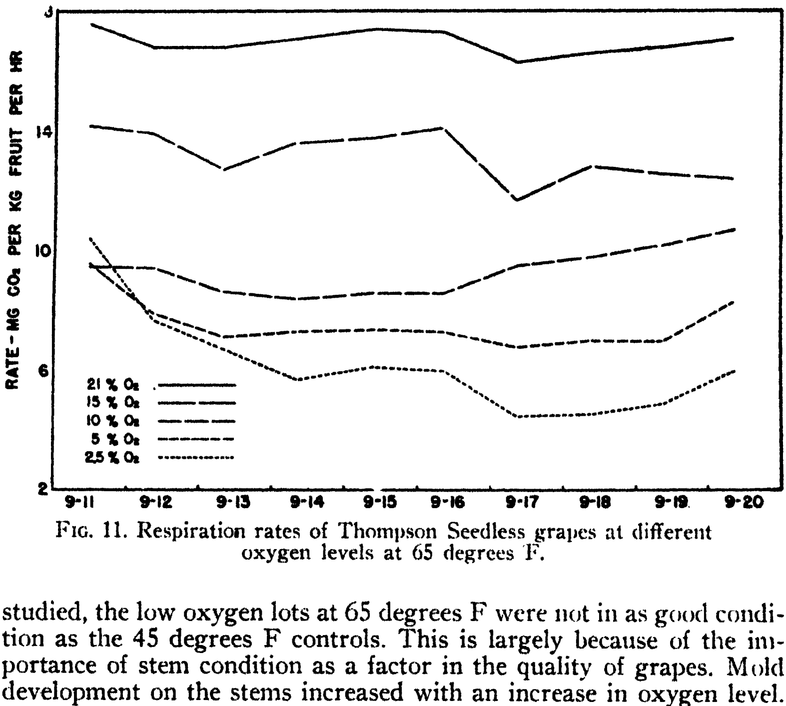

FIG. 11. Respiration rates of Thompson Seedless grapes at different oxygen levels at 65 degrees F.

studied, the low oxygen lots at 65 degrees F were not in as good condition as the 45 degrees F controls. This is largely because of the importance of stem condition as a factor in the quality of grapes. Mold development on the stems increased with an increase in oxygen level. Differences in the oxygen level, however, failed to produce any visual differences in ripeness or any noticeable changes in flavor of the fruit. Shattering of berries from the cluster, an important problem with this variety, was likewise not influenced by the oxygen level.

DISCUSSION

At the holding temperature of 65 degrees F all fruits except grapes held at oxygen levels of 10 per cent or above, showed an upward trend in respiration during the 10-day holding period. Except for Bartlett pears and Santa Rosa plums there was also a small increase in respiration rate at lower oxygen levels.

A reduction of the oxygen in the surrounding atmosphere resulted in a lower respiration rate of Royal apricots, Santa Rosa plums, Primrose peaches, Bartlett pears and Thompson Seedless grapes, and in general this decrease was in proportion to the oxygen reduction. A variety of sweet cherry similar to the Bing showed reduced respiration only when the oxygen was reduced to 5 per cent or below.

Reduction in respiration rate was reflected in the general coloring and softening of the cherry, apricot, plum, peach, and pear fruits. No maturity differences were noticeable in the grapes but the latter developed less mold growth on the stems in reduced oxygen. Cherries and apricots held in oxygen concentration of 30 to 100 per cent failed to show any higher respiration rate than concomitant samples held in air.

Fruit held for 10 days at 40 degrees F showed considerable variation in respiration behavior. Cherries at all oxygen levels, after an initial reduction, showed an increase in respiration rate with storage time. On the other hand Primrose peaches, except in 2½ per cent O_2 showed a general decrease in respiration rate. Royal apricots and Santa Rosa plums were intermediate in their behavior, showing an initial decrease for from 1 to 4 days, followed by a leveling off. The Santa Rosa lot held in air showed a small increase after holding for 3 days, but this is considered of doubtful significance. The actual respiration rates with Bartlett pears are in doubt due to temperature fluctuations. No trials were made with grapes.

In general a 2.5 per cent oxygen level at 65 degrees F reduced metabolic activity to such a low point that there was little or no difference between the ripeness of the fruits following a 10-day period at 65 degrees F and those held at 40 degrees F. Furthermore, subsequent ripening changes were similar. Low oxygen at 40 degrees F had little or no apparent effect on ripening even with a marked effect on respiration rate. Based on limited trials with cherries and apricots, oxygen levels above that of air failed to influence ripening appreciably, although there was some indication that at 65 degrees F the fruits held in 100 per cent O_2 were slightly less ripe at the end of 10 days than those held in air.

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Transpiration of Apples in Cold Storage[1]

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WATER makes up approximately 85 per cent of the weight of fresh apples. Some of this water is lost through the skin by transpiration. Successful storage operation keeps this water loss to a minimum by maintaining low temperatures and high relative humidity. When the fruit loses between 5 and 7 per cent by weight the skin becomes wrinkled, the flesh loses its crispness and the fruit is reduced in volume. The Rhode Island Agricultural Experiment Station has been studying various aspects of this problem (1, 2, 3). Additional data are presented in this paper.

Data on the transpiration rate of apples subjected to controlled humidities revealed a much more rapid rate of water loss at the normally recommended 85 per cent relative humidity than had been expected (3). These data were secured with Golden Delicious apples suspended in 5-gallon glass jars over sulphuric acid solutions. Some of the data are presented in Table I.

TABLE I—TRANSPIRATION OF GOLDEN DELICIOUS APPLES SUBJECTED TO VARYING HUMIDITIES (32 DEGREES F)

Relative Humidity (Per Cent)	Transpiration Loss (Per Cent)					
	Nov	Dec	Jan	Feb	Mar	Total
95	0.59	0.55	0.51	0.50	0.48	2.63
90	1.06	0.99	0.87	0.80	0.77	4.49
85	1.41	1.15	1.07	1.00	0.91	5.54
80	1.89	1.48	1.17	1.15	1.00	6.69
75	2.18	1.59	1.33	1.30	1.20	7.60
70	2.60	1.87	1.43	1.40	1.29	8.59

If the water losses occurring during harvest and up until the time the experiment started, November 1, 1945, are added to the loss anticipated when the fruit was exposed for sale it seems that only fruit stored at approximately 95 per cent humidity could be expected to resist shrivelling for any length of time.

It has been observed that fruits placed on top of boxes in storage shrivel more rapidly than those inside containers. When direct expansion ammonia or brine pipe refrigeration is replaced by blowers, many growers have reported larger losses from shrivelling. It has been suggested that the greater air movement was responsible. While air movement does increase transpiration somewhat (3, 4), this does not account for the high rates presented in Table I where air movement was almost completely restricted. Experiments were initiated to secure more information on this subject.

[1]Contribution No. 715 of the Rhode Island Agricultural Experiment Station, Kingston, Rhode Island.

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Assistance from the Refrigeration Research Foundation is gratefully acknowledged.

Two storage rooms having a volume of 500 cubic feet were constructed as nearly alike as possible except for the system of refrigeration. In one room cooling was secured by overhead vacuum plates; in the second room a blower was used. The storages were thermostatically controlled and set at a temperature of 32 degrees F ± 1½ degrees. Similar test lots of 27 bushel boxes of fruit, arranged in three layers of nine, were placed in each room. Weighed Rhode Island Greening apples were placed in the centers of three boxes in each tier so that on the horizontal plane one box was completely surrounded, a second had one side open to the aisle, and the third was a corner box with two sides exposed. The data on transpiration are presented in Table II. It will be noted that the fruits in the storage with forced air movement lost from 16 to 55 per cent more than those in the other storage. The variation in loss between layers was somewhat less with air movement. The loss in the top layer did not vary as much as in the middle or bottom layers under the two systems. Since relative humidity is considered one of the principal factors determining water loss and was not controlled in these two rooms, another experiment was devised.

TABLE II—TRANSPIRATION OF RHODE ISLAND GREENING APPLES UNDER TWO REFRIGERATION SYSTEMS (32 DEGREES F)

Layer	Per Cent Weight Loss				Per Cent Increase
	Jan 2 to 11	Jan 11 to 24	Jan 24 to Feb 5	Total	
		Plates			
Bottom	0.29	0.33	0.31	0.93	
Middle	0.20	0.31	0.26	0.77	
Top	0.24	0.48	0.41	1.13	
				2.83	
		Blower			
Bottom	0.39	0.53	0.51	1.43	53.8
Middle	0.33	0.41	0.45	1.19	54.5
Top	0.34	0.48	0.49	1.31	15.9
Average	—	—	—	3.93	38.9

Two small identical chambers were built in a large room of a commerical warehouse cooled by brine coils. The chambers were constructed of heavy building paper on light wooden strips that ran from the floor to the ceiling. A doorway was left open in each case. Under these conditions, similar temperature and humidity could be expected and the small volume of fruit in the test would not materially alter conditions in so large a room.

For this experiment Baldwin apples were used; 10 marked and weighed fruits were placed in each of the 18 boxes in both chambers. Besides the fruits in containers, apples were suspended on string in the air and placed on the edge of boxes near the entrance. To secure air movement a 16-inch household fan was placed on a box just inside the door of one chamber. Data are presented in Tables III and IV.

Air movement increased water loss about 25 per cent for exposed fruits and nearly 55 per cent for fruit in boxes. Thus, it is apparent that factors other than air movement are effecting water loss of fruit. From the data available the assumption was made that the large increase in

TABLE III—WATER LOSS OF BALDWIN APPLES IN BOXES IN SPECIAL CHAMBERS IN COMMERCIAL WAREHOUSE (1945–1946; 31 DEGREES F) PER CENT WEIGHT LOSS OF TEN APPLES IN EACH OF EIGHTEEN BOXES

Dates Weighed	Still Air	Air Movement	Per Cent Increase
Nov 29	——	——	——
Dec 3	0.285	0.283	——
Jan 3	0.283	0.424	——
Jan 25	0.220	0.363	——
Mar 7	0.373	0.723	——
	1.161	1.793	54.56

TABLE IV—WATER LOSS OF BALDWIN APPLES IN SPECIAL CHAMBERS OF A COMMERCIAL WAREHOUSE (31 DEGREES F—JANUARY 10 TO MARCH 1, 1946, G/KG)

	Still Air	Air Movement	Per Cent Increase
Apples hanging in air	18.9	22.9	21.2
Apples on edge of box by door	18.7	23.7	26.7

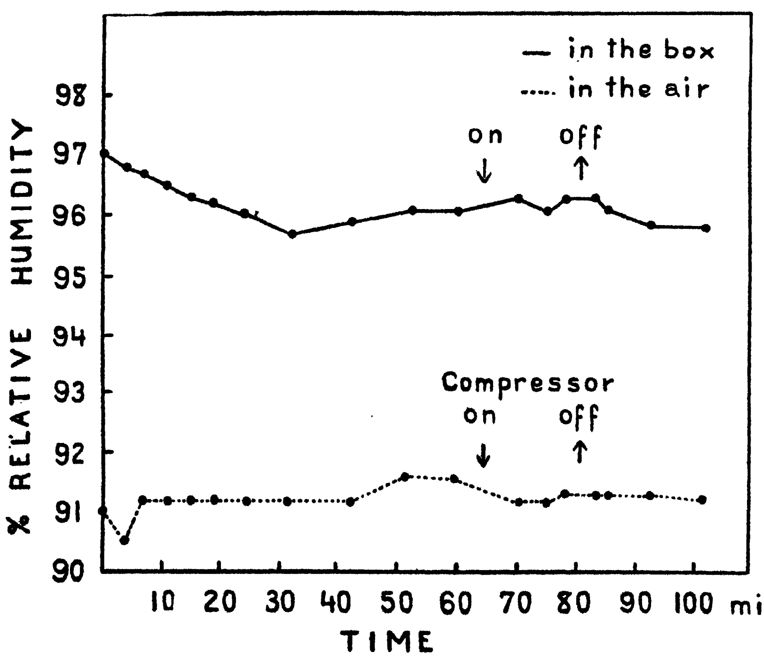

FIG. 1. Relative humidity of air in middle of a box of apples as compared with that of air 3 inches above top of box in storage cooled by overhead vacuum plates.

water loss under air movement conditions was not due to air movement as such but to a change in the humidity to which the fruit was subjected. This theory was confirmed by our data on tight versus open

boxes, where a decrease in water loss of 25 to 30 per cent was secured in tight boxes. It was assumed that where readings with a sling psychrometer showed a relative humidity of 85 per cent under plate refrigeration, the humidity inside boxes in the middle of a stack might well be 92 or 93 per cent. Under air movement conditions it appeared that the humidity inside and outside the stack was more nearly equal.

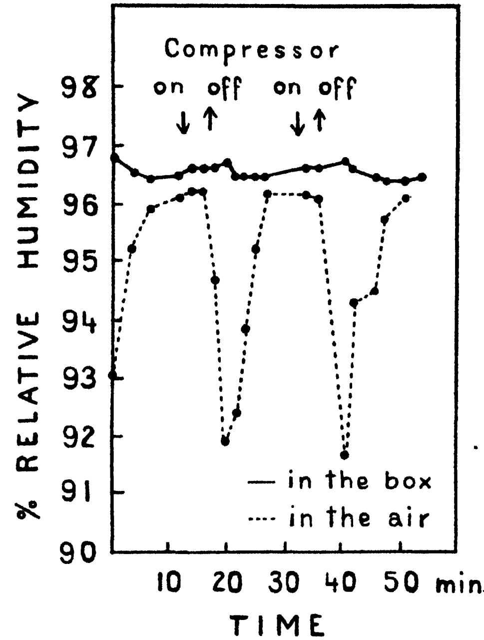

FIG. 2. Relative humidity of air in middle of a box of apples as compared with that of air 3 inches above top of box in storage cooled by blower.

Recently we have secured units, about ½ inch in diameter and 2 inches long, called Electric Hygrometer Sensing Elements, built by the American Instrument Company, which allow the measurement of humidities inside containers by means of electrical connections which pass to instruments outside the storage.

The 500-cubic-foot storage rooms previously referred to were used. Elements were placed in the center of a box of apples which was, in turn, surrounded by other boxes of fruit. In this way air circulation around the test box was similar to that around most boxes in the usual storage stack. Another element, suspended in the air 3 inches above the top box, gave a reading for the air surrounding the stack. The boxes of fruit had been in storage from 2 to 3 months and could be expected to have approached equilibrium at storage humidity. Prior to use, the test box was thoroughly soaked in water so that it would not be a drying influence.

In this experiment we were interested in a comparison of humidity inside and outside the box under plate and blower cooling and not in the humidity itself. A high relative humidity existed, especially in the storage with the blower. Data on this experiment are presented in Figs. 1 and 2.

Fig. 1 shows a difference of about 5 per cent relative humidity inside and outside the box under plates. It will be noted that the humidity reading varies with time only about 1 per cent. Readings were taken at approximately 5-minute intervals and only one "on" and "off" cycle for the compressor is covered.

In Fig. 2 it will be observed that relative humidity inside the box is quite constant and at a high rate. The humidity in the outside air varies considerably, dropping rapidly after each "on" cycle but rising before the thermostat starts the compressor again. The difference between the two lines is considerably less on the average than is the case in Fig. 1.

It is evident from these data that the recorded humidity in the aisle of a blower-cooled storage is only slightly below that of the air surrounding the apples in the middle of the stack. On the other hand, the humidity inside the box may be expected to be considerably higher than that recorded in the aisle of a storage cooled with plates. Under the conditions of this particular experiment, one might expect the fruits to transpire at approximately the same rate. On the basis of humidity recorded in the aisles, considerable difference in transpiration rate might be expected.

These data explain some of the inconsistencies of water loss in storage where the only humidity measure has been a sling psychrometer used in the aisle. In blower-cooled storage, a much higher average humidity must be maintained to approach equal control of shrivelling. Moreover, the humidity reading may be expected to vary considerably, depending upon the time during the refrigeration cycle that the reading is taken. It is recognized that various engineering considerations influence transpiration losses with all cooling systems. Studies are under way and will be reported in subsequent papers.

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The Effect of Sulfur and Sulfuric Acid Applications Upon Soil pH Values and Cork Spot Development of Buerre d'Anjou Pears[1]

By F. L. OVERLEY and D. F. ALLMENDINGER,[2] *The State College of Washington, Tree Fruit Experiment Station, Wenatchee, Washington*

CORK spot, a disorder of Buerre d'Anjou pears has been prevalent in Washington Orchards for many years (1, 2). While the cause of the disorder has not been established, it has been reported to be more severe on heavily pruned trees (2), on trees bearing light crops, and much worse in some seasons than in others (7). Apparently, cork spot may appear on trees grafted on either Japanese or French stock (9). Application of wax sprays to reduce foliar transpiration have not influenced the prevalence of cork spot (4).

Since attempts to decrease the disorder by application of several minor elements to the soil or through tree injections have been unsuccessful (1, 2, 5, 6, 8, 9, 10), the investigation herein reported was conducted to determine if the increased availability of certain elements brought about by increasing soil acidity would have an influence on the prevalence of cork spot.

MATERIALS AND METHODS

A block of Rome Beauty apple trees on the grounds of the Tree Fruit Experiment Station of the Washington Agricultural Experiment Stations at Wenatchee was interplanted in 1930 with Buerre d'Anjou trees. The soil in which these trees were growing is classed as Cashmere gravelly, coarse, sandy loam varying from the normal in that it contains a higher percentage of silt and clay (3). Some fruit on each tree developed cork spot after the trees started to bear in 1938. A series of plots was then established to determine to what extent the soil acidity could be altered by the application of sulfuric acid or sulfur, and to what extent, if any, this would influence the prevalence of cork spot.

Beginning in 1939, the soil around each of 12 trees selected at random was sprinkled with commercial sulfuric acid to a distance of 6 feet from the trunk. Applications were made at weekly intervals during the growing season with the acid diluted in 5 gallons of water. The treatments for each tree were as follows:

1939—20 milliliters each week from March 15 to July 15	360 milliliters
1940—20 milliliters each week from March 18 to September 9, except 75 milliliters applied on April 22 and 29	620 milliliters
1941—20 milliliters each week from March 3 to September 15	580 milliliters
1942—60 milliliters each week from April 1 to October 1	1620 milliliters
1943—100 milliliters each week from April 1 to September 1	2300 milliliters
1944—150 milliliters each week from May 2 to August 23	2550 milliliters

[1]Published as Scientific Paper No. 747 State College of Washington, Institute of Agricultural Sciences and Agricultural Experiment Stations.

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In 1940 a finely ground sulfur, used in making lime sulfur solution, was applied to 10 trees at the rate of 20 pounds per tree, beginning April 26 and continuing each month thereafter for a total of 5 months, making a total of 100 pounds sulfur applied to the soil around each tree in one season.

Beginning in 1940, soil samples were taken in the fall with a soil tube from the treated area around each of six trees from the treated plot and from adjacent untreated trees. Three soil borings around each tree were made and the samples aggregated according to the following depths: 0 to 6 inches, 6 to 12 inches, 12 to 24 inches and 24 to 36 inches. In 1942 the sample depth was increased to include the depth of 36 to 48 inches. The samples were air dried, screened through a 2-mm sieve and the pH determined with a Beckman pH meter using a soil water ratio of 1 to 2.

The cork spot development in the fruits was determined by an examination of all the fruits from treated and untreated trees. If, from the external appearance of the fruit, there was any question as to the presence or absence of cork spot, the individual fruits were cut with a knife and the diagnosis made upon the basis of the internal examination.

PRESENTATION OF DATA AND DISCUSSION

Effect of Soil Treatment on pH:—The average pH values for the years 1940 through 1944 representing the determinations for six trees in the untreated plot and six trees treated with sulfuric acid are presented in Table I.

TABLE I—AVERAGE pH VALUES FOR UNTREATED SOIL AND SOIL TREATED WITH SULFURIC ACID*

Depth of Soil (Inches)	Treated With Sulfuric Acid					Untreated				
	1940	1941	1942	1943	1944	1940	1941	1942	1943	1944
0–6	6.4	6.3	6.2	5.3	4.5	6.7	6.5	6.4	6.4	6.3
6–12	6.9	6.9	6.5	5.7	5.6	7.0	6.8	6.6	6.7	6.7
12–24	7.0	7.1	6.7	6.0	6.5	6.9	7.1	6.8	6.6	6.7
24–36	7.1	7.1	6.9	6.0	6.4	7.0	6.9	6.8	6.8	6.5
36–48	—	—	6.8	6.1	6.4	—	—	6.9	6.9	6.7

*Average pH values determined by averaging H-ion concentrations.

These data show little difference between treated and untreated soil until 1943 at which time the surface foot of the plot receiving sulfuric acid was approximately 1 pH unit lower than the untreated. In 1944 the difference in the surface 6 inches was approximately 2 pH units with the second 6 inches remaining approximately 1 pH unit lower than the untreated.

The soil below 1 foot seems not to have been materially affected since there was little difference in the pH values of the treated and untreated plots, except possibly in 1943 when the data indicated total possible differences of less than 1 pH value.

It is apparent that the application of approximately 7900 milliliters of concentrated sulfuric acid to the soil in a circle to a distance of 6 feet from the tree trunk (approximately 70 milliliters per square foot)

over a period of 6 years increased the acidity of the first foot from 1 to 2 pH units, with little effect below that depth.

In Table II are presented data from the plots treated with sulfur, and from the plots receiving no treatment.

TABLE II—AVERAGE pH VALUES FOR UNTREATED SOIL AND SOIL TREATED WITH SULFUR*

Depth of Soil (Inches)	Treated With Sulfur					Untreated				
	1940	1941	1942	1943	1944	1940	1941	1942	1943	1944
0–6	3.2	2.6	3.0	3.1	3.9	6.6	6.6	6.4	6.4	6.5
6–12	5.2	3.7	3.5	3.6	4.2	6.8	7.1	6.7	6.7	6.6
12–24	6.2	4.5	4.2	4.0	4.6	7.1	7.2	6.8	6.8	6.7
24–36	6.6	4.9	4.6	4.8	4.9	7.4	7.4	7.0	6.7	6.9
36–48	—	—	4.9	4.2	6.7	—	—	7.0	7.1	7.1

*Average pH values determined by averaging H-ion concentrations.

These data indicate that in 1940 there was a marked increase in acidity of the soil that received the sulfur, particularly in the upper foot. This is evidenced by pH values of 3.2 and 5.2 for the first and second 6-inch-depths for the soil that received the sulfur as contrasted to values of 6.6 and 6.8 for corresponding samples of the untreated soil. By 1942 the pH of the soil had been markedly reduced throughout the 4-foot sample area as evidenced by values of 3.0 to 4.9 for the treated plot as compared with values of 6.4 to 7.0 for the untreated. Considerable differences in pH were still apparent in 1944, except possibly for the 4th foot, 5 years after the application.

These figures show that the 100 pounds of sulfur applied per tree (approximately 1 pound per square foot) lowered the pH value considerably through a depth of at least 4 feet, which should include at least a major portion of the root area of the trees.

Percentage of Fruit Showing Cork Spot:—The average number of fruits per tree for 10 trees of each plot with the per cent of fruits showing cork spot is given in Table III.

The data in Table III indicate that the addition of the sulfuric acid or sulfur did not reduce the incidence of cork spot on these trees. Considerable variation from year to year is evidenced. For the last 4 years when the effect of the treatments should have been most pro-

TABLE III—AVERAGE NUMBER OF FRUITS PER TREE AND PER CENT OF FRUITS SHOWING CORK SPOT

Year	Trees Receiving Sulfuric Acid		Trees Receiving Sulfur		No Treatment	
	No. Fruits Per Tree	Per Cent Cork Spot	No. Fruits Per Tree	Per Cent Cork Spot	No. Fruits Per Tree	Per Cent Cork Spot
1939	58	5	31	10	73	4
1940	52	47	19	77	35	80
1941	120	42	160	28	168	36
1942	95	9	108	6	138	12
1943	289	3	299	5	413	5
1944	175	21	228	12	309	10
Average*	170	16	199	12	257	13

*Average for last 4 years based on total number of fruits and total number of fruits showing cork spot.

nounced, 13 per cent of the fruit on the untreated trees showed cork spot as compared with 12 per cent on the trees receiving sulfur. The trees that had received the sulfuric acid had a slightly higher average, 16 per cent.

The application of the sulfur or sulfuric acid did not cause visible abnormal conditions in the trees although the sulfur did prevent cover crop or weed development.

Summary

The application of approximately 70 milliliters of concentrated sulfuric acid per square foot over a period of 6 years materially affected the soil acidity only of the surface foot.

The application of approximately 1 pound of sulfur per square foot materially increased the acidity of the soil through a depth of 4 feet, this reduction still persisted 5 years after the application.

The incidence of cork spot of Buerre d'Anjou pears was not influenced by either the application of sulfur or sulfuric acid.

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Can Unproductive Apple Seedlings Be Eliminated From the Nursery Row?[1]

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An accurate knowledge of the internal structure of leaves was made possible during the early part of the nineteenth century by the introduction of improvements in the microscope. Previous to this period the records are chiefly concerned with the surface tissues of the leaf. Hooke published drawings of the epidermal cells and of the hairs on the under surface of the stinging nettle in his "Micrographia" in 1665, and 10 years later Malpighi was the first person to observe the stomata of a leaf. There was now a period of more than 150 years before the next important contribution appeared.

De Candolle (3) described the upper and lower epidermis and an intermediate zone between them to which he first gave the name "mesophyll" in 1827.

With the publication of "The Origin of Species" in 1859, botanists were provided with an incentive to examine plant tissues in detail and thus test the evidence provided by microscopic observations of the adaptation of plants to their environments. This stimulus resulted in the publication of a considerable amount of work on the anatomy of various parts of the mature plants.

From this research our knowledge of the factors affecting photosynthesis have gradually emerged. These are now generally regarded to include the carbon dioxide supply, light, temperature, water supply, chlorophyll content, and the internal factors.

In recent years a large number of investigators have studied the photosynthetic activity of apple leaves and the effect of certain spray residues on the rate of photosynthesis. In general, these studies show that the residues on the two surfaces of the leaves not only reduce photosynthetic activity, but also that the stronger the spray material, the greater the reduction in the rate of photosynthesis.

The importance of the leaf in relation to fruit bud formation and the relationship between leaf area and fruit size has been demonstrated by numerous workers, and a large number of investigators have reported on the relationship between yield and other growth characteristics such as shoot and spur length, and trunk circumference.

That a more extensive intercellular space in apple foliage is reflected in greater photosynthetic activity has been set forth by Pickett and Birkeland (9), who, in fact, conclude that the extent of the internally exposed surface of apple leaves is more important than the chlorophyll content as a factor partially governing photosynthetic activity. Further studies on the relation between the internal structure of the leaf and its activities showed that varieties differed in the ratio R of the internally exposed surface to the externally exposed surface, that this value was greater in field-grown apple leaves than in those grown in the greenhouse. It was also found that repeated applications of certain spray

[1]Abstract of a Thesis. Indebtedness is gratefully acknowledged to Dr. M. J. Dorsey for aid in carrying out the work.

materials reduced this value in both the greenhouse and field. The spray materials were found to shock or check normal cell development in apple leaves with each application throughout the growing season; mild sprays did not exert so great a dwarfing effect as did the stronger materials. The total depth of palisade tissue was closely correlated with the R value and could be used to estimate this ratio, thus saving approximately 90 per cent of the time needed in the standard calculations.

This work Pickett and Birkeland (9) suggested that assuming the R value to be an important factor in photosynthetic activity, the lower ratio of York Imperial may be offered as one of the factors contributing to the biennial bearing habit of this variety in the Missouri Valley as well as in the Shenandoah Valley where this variety is grown so extensively. It was also suggested from these studies that this factor may be used for determining vigor of seedling trees while still in the nursery, and thus save several years in selection.

In view of the above investigations of the relationship of the internal structure of apple leaves and their photosynthetic behavior, along with environmental and varietal differences, it was proposed to make a study of the genetic significance of this factor. At the University of Illinois there was presented the opportunity of working with several varieties and species, and with 119 seedlings from a Jonathan x Yellow Transparent cross, some of which had come into bearing. It was suggested that if the internal structure of the leaves was related to fruitfulness, this factor may become a valuable tool for the fruit breeder when working with the tree fruits in which there is such a slow turnover of the generations. The varieties, species, and hybrids selected for this study were chosen because of their interest to the plant breeder.

Materials and Methods

From June 18, 1946, to June 29, 1946, 10 to 20 apparently uninjured leaves of an average size for the tree were collected from 10 varieties, 119 hybrid seedlings from a Jonathan x Yellow Transparent cross, and from 13 species. The leaves selected were from near the middle of the new shoots which were from 6 to 12 inches long. The portions of the leaves used for microscopic study were located near the midrib and midway between the basal and apical regions. The marginal and midrib portions of each leaf were discarded. Only one piece, about 1 by 3 centimeters, was taken from a single leaf.

These leaf pieces were placed in a 1 per cent chromo-acetic acid killing and fixing solution and evacuated. After leaving them in the killing and fixing solution for 24 hours, they were washed, dehydrated with tertiary butyl alcohol, and imbedded in paraffin. The leaves were placed five deep in the paraffin blocks, which enabled one to section five at a time for mounting on slides, thus permitting a much more rapid study of the material.

One set of slides was made from each block of leaves, a set of slides consisted of one slide with cross sections of five leaves and one slide with tangential sections of one leaf. All sections were 8 microns thick. They were stained with 0.5 per cent Safranine 0 in 50 per cent alcohol,

and mounted in balsam. Three to five sections were placed on each slide.

In order to determine the internally exposed surface of a leaf, drawings were made from the slide at a high magnification. When these drawings were measured and the magnification determined, the amount of internally exposed surface could be readily calculated. The calculations and drawings were made in a similar manner to those described fully by Pickett and Birkeland (9).

Presentation of Data

This technique has shown that the internal structure of the apple leaf is related to photosynthetic activity. The varietal differences found by previous research indicate that this factor is genetically controlled, though modified by such factors as light, spray materials, and fertilizers.

Varieties:—The usefulness of the knowledge of the internal structure of leaves as an index of performance was first studied in varieties since we know more about them than either species or seedlings. The varieties for this study were chosen because of their importance commercially and also because of well recognized differences in adaptability. For instance, of the 10 varieties selected, Duchess, Wealthy, and McIntosh are better adapted to more northern regions, with McIntosh being beyond its natural range in Illinois. Grimes Golden, Winesap, and York Imperial, on the other hand, are considered southern varieties. Golden Delicious and Delicious, while grown widely, are well adapted to Illinois, though Delicious is at its best in the Pacific Northwest. The measurements of the length of palisade cells are recorded in Table I.

TABLE I—Average Length of Palisade Cells of Varieties in Microns

Variety	Length of Palisade (Microns)
Delicious	108.52
Golden Delicious	105.34
Grimes Golden	111.81
Jonathan	109.89
McIntosh	100.68
Duchess	110.48
Wealthy	124.38
Winesap	104.41
Yellow Transparent	103.70
York Imperial	97.24

In general, the varieties in Table I ranked in the same order in relation to one another as those previously studied in a different region by Pickett (5, 6), Pickett and Kenworthy (10), and Pickett and Birkeland (7, 8, 9), and an analysis of variance showed more variability between varieties than between leaves. The leaves of McIntosh, however, were extremely variable. This may possibly be explained on the basis that McIntosh is beyond its best range in Illinois and great variability could be expected.

Species:—The measurements of the length of palisade cells of the 13 species are presented in Table II.

TABLE II—AVERAGE LENGTH OF PALISADE CELLS OF DIFFERENT SPECIES IN MICRONS

Species	Length of Palisade (Microns)
Malus prunifolia	115.68
Malus floribunda	133.20
Malus halliana	160.39
Malus ringo	117.75
Malus toringo	84.26
Malus sieboldi	92.78
Malus atrosanguinia	126.00
Malus ioensis	91.52
Malus baccata	104.67
Malus coronaria	81.90
Malus sikkimensis	138.38
Malus micromalus	125.96
Malus zumi calocarpa	109.73

There was more variability between species than between leaves within a species, again indicating genetic control of leaf structure.

Malus halliana possessed the greatest depth of palisade tissue of any species or variety studied, though it is beyond its natural range in Illinois. This might indicate, as with the McIntosh variety, that though the internal structure is genetically controlled and modified to a certain extent by environmental factors, when the tree is beyond its natural range the other variables become more influential.

Hybrids:—A study of the progeny of a Jonathan x Yellow Transparent cross made in 1932 was undertaken to determine whether there was any relation between leaf structure or growth and yield. Estimates of the yield were made on the trees under study just before harvest, and the trees were grouped into five classes — those with no fruit, a light crop, ½ bushel, 1 bushel, and a full crop. Growth records were taken during the dormant season, including height of tree, greatest spread, and trunk diameter. The results of the studies of this population are presented in Table III.

TABLE III—AVERAGE DEPTH OF PALISADE CELLS, HEIGHT, BREADTH, AND TRUNK DIAMETER, FOR EACH OF FIVE YIELD CLASSES

Yield	Number of Trees	Depth of Palisade (Microns)	Height of Tree (Inches)	Trunk Diameter (Inches)	Breadth of Tree (Inches)
None	43	92.78	189.1	5.43	170.77
Light crop	38	101.47	210.1	6.55	203.84
½ bushel	10	102.78	216.3	6.81	213.10
1 bushel	13	100.63	220.8	7.08	221.69
Full crop	15	96.43	227.7	7.95	233.87

An analysis of variance of the growth factors as determined by height, trunk diameter, and spread of tree, showed significant differences between these values, each of these measurements increasing progressively with each increase in yield.

There was no significant differences in the depth of palisade cells among the yield classes of light crop, ½ bushel, and 1 bushel, but when these three classes were grouped together under light crop and an analysis of variance then made of the length of palisade cells, the variability or mean square between yield groups was highly significantly greater than the variability between trees within these groups.

Since the work here presented was with trees in a different region and more mature than that reported on by Pickett and Birkeland (9), with several species, varieties, and seedlings not previously studied, it was believed necessary to redetermine the ratio R. The R value was thus completely worked out on 100 leaves in order to estimate the other 1950 under investigation. The estimate of R value or regression coefficient equaled 0.1307P + 2.87 with a standard error of estimate of 1.26, and the correlation between P and R was + 0.81, which is highly significant.

An extra layer of palisade mesophyll was frequently formed on the lower epidermis of Duchess and Delicious, which was probably due to light striking the under side of the leaf, Bergen (1), but due to the prevalence of this characteristic in certain varieties, it may also be genetically influenced.

Discussion

These results indicate that while under most conditions the internal structure of the leaf is primarily determined by genetic factors and modified to a certain extent by environmental factors, if the tree is grown beyond its natural range of adaptation the environmental factors become more influential and induce extremes in variation.

The data on productivity and growth factors show that the trees which had not yet come into bearing were the smallest, and that the trees were larger in each succeeding yield group, with the full crop class being the largest. An analysis of variance showed these differences to be highly significant. This is in agreement with a large number of investigators.

The three groups having a light crop possessed a greater total depth of palisade tissue than the trees which had never borne fruit, the difference being highly significant. The trees having a full crop showed less palisade depth than those with a light crop, though more than those with no fruit. This might indicate that a full crop competes with the leaves for nutrients to such an extent that the internal structure is reduced to less than in those trees with a slight crop. Chandler (2) has reported that leaf size is reduced on trees with a heavy crop.

If it were assumed, and this has been found true in previous research, that the internal structure is much the same in a 1-year-old apple tree as in the mature tree of the same clone, a percentage of seedlings based on internal structure of the leaves might have been discarded with the following results. Of the 104 trees in the light crop and no fruit classes, 43 had no fruit up to the present time and 61 had borne a light crop. If all trees with leaves having a total depth of palisade of less than 100 microns had been discarded, there would have remained 42 trees which had borne and only six which yielded no fruit up to 15 years of age, or a much smaller percentage of trees which had not borne fruit up to this time.

Using the depth of palisade as an index to internal exposed surface considerably shortens the time consumed in making such a study. In fact, since the palisade mesophyll contains 85 per cent or more of the internally exposed surface of the leaf, and since the chloroplasts are

much more numerous in the palisade than in the spongy mesophyll, Pickett and Birkeland (9), one might reasonably suggest that the total depth of palisade is a better index to photosynthetic activity than is the extent of internally exposed surface.

Since growth of tree as measured by trunk diameter, height, and spread, and total depth of palisade tissue in the leaf, are significantly different in the yield groups chosen, these should be characteristics in a young tree which could be used to fortell its future vigor and productivity. Vigor of growth is cumulative, however, and difficult to measure in a young tree, due to variability in the size of trees in the nursery as affected by environmental factors such as location and cultural treatment. In fact it has been found that there is no high positive correlation between the size of a 2-year-old tree in the nursery and a 9-year-old tree (4). The total depth of palisade, however, is approximately the same in a 1-year-old tree as in a mature tree, and is much less variable in the young tree. Therefore, the depth of palisade might actually give a truer picture of the potentialities of the tree in the nursery than on the more mature tree after environmental factors have had time to gain expression.

This is a preliminary report and much work must be done to further investigate the reliability of this technique, but the trends thus far indicate that it might be possible in apple breeding experiments to eliminate a large number of seedling trees from the nursery because they do not possess the gene complex which would produce a vigorous productive tree. This would assure the breeder of two important characteristics for a new variety, namely, vigor of growth and productivity. The breeder could then devote more time to other desirable characters such as disease resistance, keeping quality, dessert and cooking quality, color of fruit, and hardiness in a population from which the low producing trees and those which would come into bearing late, if at all, were eliminated.

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Scion Rooting in Dwarf Pear Trees[1]

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STANDARD pear trees are often relatively slow in coming into bearing. It has been suggested that earlier bearing might result from planting dwarf trees (on quince) deeply, with the idea of eventually getting scion rooting and a tree of standard size, mainly or wholly on its own roots. To give this idea a practical test, trees of four varieties (Anjou, Bartlett, Clapp Favorite, and Vermont Beauty) on Quince A and French pear seedlings were planted at the Ontario Horticultural Experiment Station in the fall of 1932.

Of each variety there were five standard trees, five dwarf trees with the union about 6 inches below ground level (dwarf deep), and five dwarf trees with the union about 1 inch above ground level (dwarf shallow). The trees were planted in this order in single-tree comparisons. At the same time three dwarf Bosc trees were planted with the union at the 6-inch depth and three with the union about 1 inch above ground level. One dwarf deep Bosc tree died from blight infection in 1943. The soil in this orchard is classed as Vineland clay loam — poorly drained, high in organic matter, slightly to medium acid. Trunk circumferences, fruit yields, and size of fruit were taken annually for each tree until the fall of 1946 when the trees were dug for the purpose of making observations on scion rooting.

In the examinations of root systems of the excavated trees it was necessary first of all to work out methods of identification of pear and quince roots so that scion roots could be definitely separated from stock roots. The methods used have been reported in detail by the first author (3). All roots were measured with caliper or tape as near as possible to their origin from the main axis and from these figures the total cross-sectional area was computed. The percentage that the scion roots bore to the total root system was considered as a measure of scion rooting. The age of the scion roots was determined from a count of the annual rings at the point of origin.

RESULTS

Tree size and yield relations among these trees have already been reported for the period ending in the fall of 1945 (4), and therefore it seems unnecessary to tabulate them in this paper. Owing to poor pollination conditions, the 1946 yields were very poor and did not change the yield relations appreciably.

By the fall of 1946, after 14 years in the orchard, all of the dwarf deep trees, except three Vermont Beauty, had developed scion roots to a greater or less degree. Owing to union coverage with soil incidental to cultivation, slightly more than half of the dwarf shallow

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[1]A report of work done at Ontario Horticultural Experiment Station and Ontario Agricultural College.

trees had also developed some scion roots, but to a much lesser degree than the dwarf deep trees (Table II). Among the dwarf deep trees, the quince root was completely dead in the following numbers of trees: two Anjou, three Bartlett, one Clapp Favorite. In the other dwarf deep trees of these three varieties the quince roots were becoming of secondary importance.

It was expected that scion roots would originate very quickly from the dwarf deep trees. Such was not the case, however, as is shown in Table I. The first roots arose in Clapp Favorite in the seventh year in the orchard; in Anjou, Bartlett, and Bosc, in the eighth year; and in Vermont Beauty in the tenth year. Scion rooting commenced in the dwarf shallow trees from 1 to 4 years later, depending on variety and probably also on uneven mounding of soil over the unions in the course of cultivation.

TABLE I—Number of Years After Planting for Scion Roots to Arise

Variety	Dwarf Deep	Dwarf Shallow
Anjou	8	11
Bartlett	8	12
Bosc	8	10
Clapp Favorite	7	10
Vermont Beauty	10	11

Once scion rooting started, there was a rapid annual increase in the proportion of pear (scion) roots (Table II). Beginning in the eighth year in dwarf deep Bartlett trees, by the end of the fourteenth year 93 per cent of the root system was of pear origin and only 7 per cent of quince origin. In dwarf shallow Bartlett trees the change was from zero scion roots in the eleventh year to 21.7 per cent at the end of the fourteenth year.

TABLE II—Scion Roots as Percentages of the Total Root System After 14 Years in the Orchard (Based on Area of Cross-Section Near Point of Origin)

Variety	Dwarf Deep	Dwarf Shallow
Anjou	82.7	46.8
Bartlett	93.0	21.7
Bosc	61.2	24.1
Clapp Favorite	63.9	0.3
Vermont Beauty	38.4	18.7

Up to the time of development of the first scion roots there was little to choose between the dwarf deep and dwarf shallow trees. As soon as scion rooting took place the dwarf deep trees began to grow more rapidly and to assume a more upright habit. In yield per tree there was a slight tendency toward greater production per tree, accounted for largely by increase in bearing area. Vermont Beauty was the only exception to the above generalizations. Here the dwarf shallow trees were continuously more productive than either the standard or dwarf deep trees.

Discussion

It appears that scion rooting in deeply planted dwarf pears was much slower in developing under the conditions prevailing in this orchard than in experiments reported by Hatton (2) in England and Day (1) in California. In England the trees were not planted deeply, but in California the union was submerged 12 inches, and in fact that is the depth recommended by Day. Since the trees at Vineland were in full bearing before scion rooting became a factor, there was not the yield depression which occurred in England at an earlier age of tree.

While it is true that the deeply planted dwarf trees usually came into bearing a year or two earlier than the standard trees, it was only a few years before the standard trees surpassed the dwarfs in yield. The only justification therefore, under Vineland conditions, for using dwarf trees planted deeply in preference to standards would be that they might be planted more closely, thus compensating for the lower yield per tree. However, not knowing how large the trees of each variety might eventually become on their own roots, a closer spacing of trees would be in the nature of a gamble.

Summary

Under conditions at Vineland dwarf pear trees planted with the union 6 inches below ground level did not begin to grow scion roots until the seventh to tenth year. Then, scion roots developed rapidly, the quince root became less and less important, and in some instances was dead at the end of the fourteenth year. In this orchard scion roots did not exert a repressive influence on fruiting. Varieties varied considerably in their capacity to develop scion roots.

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Effects of Freezing on the Respiration Rate of Oranges and Lemons[1]

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CARRICK (1) has shown that respiration rate of fruits is a good index of freezing injury when visible evidences of damage are not present. These respiration studies with oranges and lemons were conducted to indicate "degree of injury" following various exposures to freezing temperatures. This method of determining freezing injury seems especially appropriate with these fruits since they may show little visible injury even though they have been frozen solid for several hours.

METHODS

Fruits were supplied by the California Fruit Growers' Exchange. Fruits were shipped to Ithaca, New York shortly after picking and experiments were conducted as soon as possible after arrival of the fruit.

Fruits were held at —7 degrees C for various periods of time as indicated in the text. The start of the time exposure to the freezing temperature was determined by the formation of actual ice crystals in the fruit. Twelve fruits other than those used in the actual respiration measurement studies were used for this determination of ice crystal formation.

Respiration measurements by the method of Carrick (1) were made for several days prior to freezing treatment. After the normal variations in respiration rate between lots were noted, the freezing treatments were given. After the fruits had thawed, respiration measurements were continued on the following day. Arrows in the figures indicate the date of the freezing treatments.

RESULTS

Washington Navel Oranges:—One lot of Navel oranges was held at —7 degrees C for 3 hours after initial ice crystal formation. A second lot was held for 6 hours. The tissue temperature of the first lot upon removal from the freezing temperature was —3.8 degrees C and that of the second lot was —4.3 degrees C. Respiration results at 0 degrees C are given in Fig. 1. The lot with the 3-hour exposure showed a 26 per cent respiratory rise the first day after treatment. This increase over normal gradually lessened as the experiment progressed. The 6-hour treatment resulted in a slightly greater increase than the 3-hour treatment. The greatest increase was noted during the first 5 days after the freezing treatment.

Washington Navel oranges were held at —7 degrees C for 1, 6, and 8 hours after initial ice crystal formation and respiration measurements were made at 20 degrees C. The tissue temperatures after the ex-

[1]This is a portion of a thesis presented for the Ph.D. degree at Cornell University entitled "Some freezing studies of certain citrus fruits" in 1927.

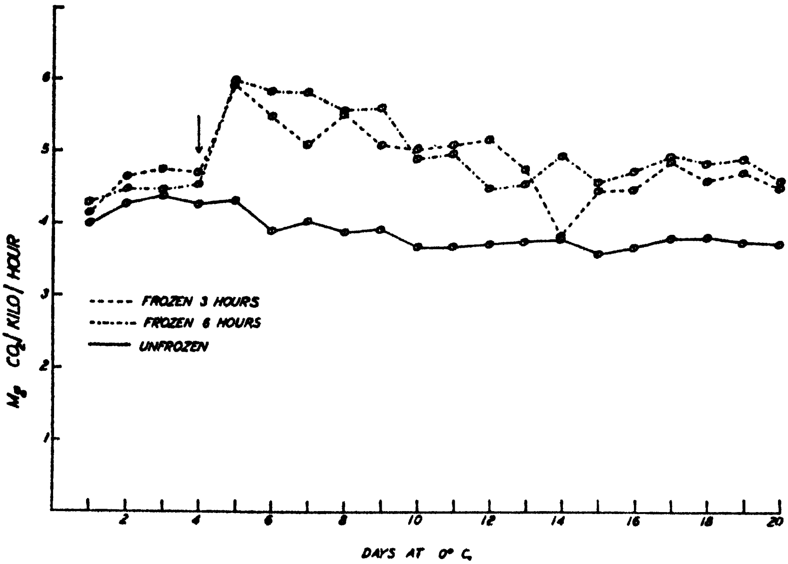

FIG. 1. Influence of freezing for 3 to 6 hours at —7 degrees C on respiration of Washington Navel Oranges at 0 degrees C. Arrow indicates date of freezing.

posures to the freezing temperature were —3.5, —4.1, and —4.7 degrees C for the 1-, 6-, and 8-hour exposures respectively. It will be seen in Fig. 2 that the 1-hour treatment resulted in a slight respiratory increase during the first 2 days after freezing. The rate then declined to values slightly below those of the unfrozen fruit. The 6-hour treatment resulted in a considerable increase during the first 2 days after treatment. Four days after treatment, the fruit had almost "normal" respiratory values. The 8-hour treatment showed a larger increase in respiration rate during the first 5 days after treatment. Respiratory values in this treatment did not decline as they did in the other two exposures to freezing.

Valencia Oranges:—This variety was held at —7 degrees for 6- and 14-hour periods to determine the effect on subsequent respiration at 0 degrees C. The 6-hour treatment resulted in an 89 per cent increase in respiration during the first day after treatment (Fig. 3). This increase declined in subsequent days but the average increase during the first 9 days after treatment was 43 per cent over normal. The 14-hour treatment resulted in a 68 per cent increase during the first 9 days after treatment. It is noteworthy here that the 6-hour treatment with Valencias had a greater effect than a similar treatment with Washington Navels.

Eureka Lemons:—Freezing treatments of 1, 3, and 6 hours duration were given Eureka lemons. The effects on respiration rate at 0 degrees C are seen in Fig. 4. An unfrozen sample was not studied in this ex-

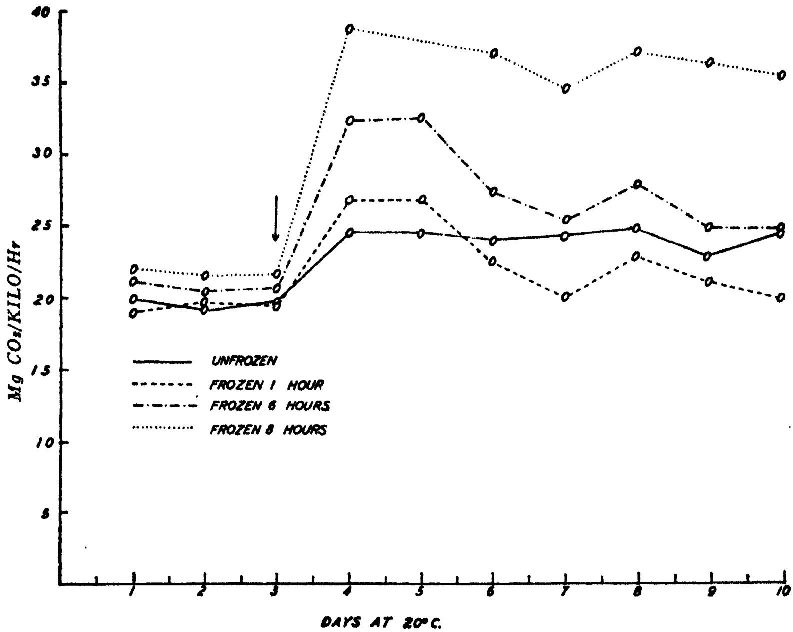

FIG. 2. Influence of freezing for 1, 6, and 8 hours at —7 degrees C on respiration of Washington Navel Oranges at 20 degrees C. Arrow indicates date of freezing.

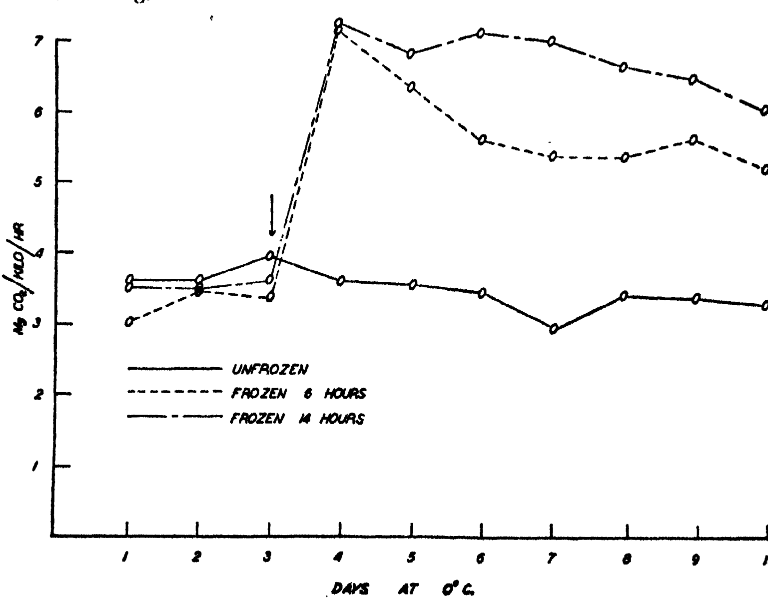

FIG. 3. Influence of freezing for 6 and 14 hours at —7 degrees C on respiration of Valencia Oranges at 0 degrees C. Arrow indicates date of freezing.

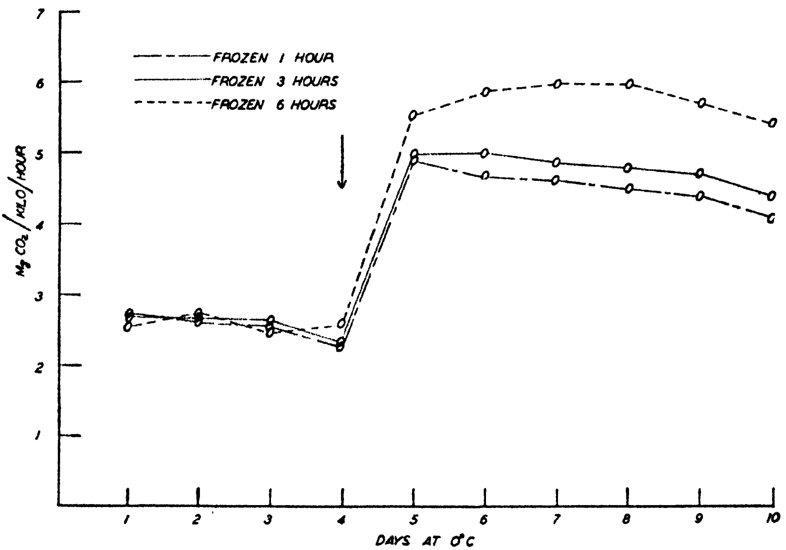

FIG. 4. Influence of freezing for 1, 3, and 6 hours at —7 degrees C on subsequent respiration of Eureka lemons at 0 degrees C. Arrow indicates date of freezing.

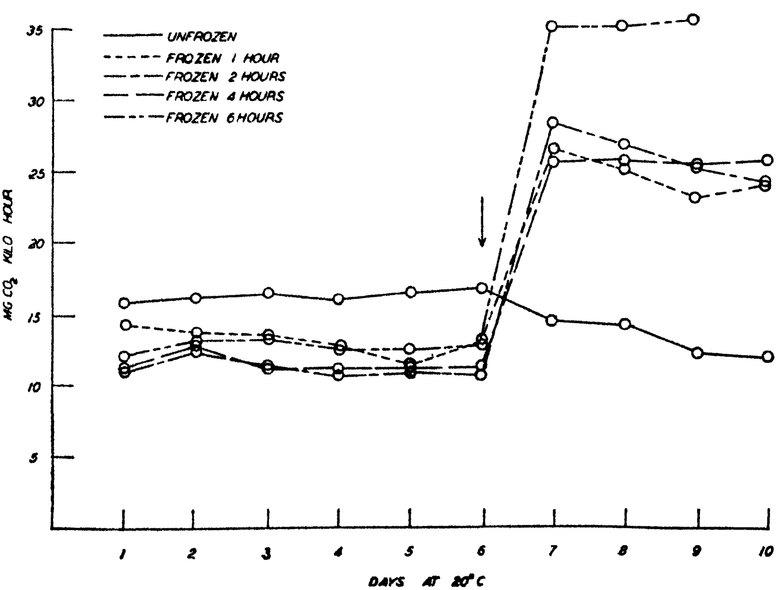

FIG. 5. Influence of freezing for 1, 2, 4, and 6 hours at —7 degrees C on respiration of Eureka lemons at 20 degrees C. Arrow indicates date of freezing.

periment; hence percentage increases in respiration are based on values prior to the freezing treatments. The 1-hour treatment resulted in a 77 per cent increase in respiration rate; the 3-hour treatment resulted in an 89 per cent increase and the 6-hour treatment in a 121 per cent increase. It would seem therefore that the effects of freezing were even more profound than on Valencia oranges.

In another experiment with Eureka lemons, the fruits were held at —7 degrees C for 1, 2, 4 and 6 hours after initial ice crystal formation. The effect of this treatment on subsequent respiration of the fruits at 20 degrees C is seen in Fig. 5. The 1-hour freezing treatment increased the respiration rate by over 80 per cent. Two hours freezing increased the rate by 136 per cent. Four hours freezing increased the rate by 112 per cent and 6 hours freezing increased it by 179 per cent.

Summary

Freezing of Washington Navel oranges and Eureka lemons stimulated the respiration rates of these fruits at both 0 degrees and 20 degrees C. This was also observed with Valencia oranges at 20 degrees C. In general, the longer the freezing treatment (—7 degrees C) given the fruit, the greater was the respiratory increase.

A given exposure to the freezing treatment seemed to have the greatest stimulatory effect on respiration of Eureka lemons. The effect was more profound on Valencia oranges than it was on Washington Navels.

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The Mineral Composition of Date Palm Foliage

By Walter Reuther, *U. S. Department of Agriculture, Orlando, Fla.*

The studies summarized in this paper were undertaken in order to obtain a background of information on which to base a sampling technique for the analysis of foliage of the date palm, *Phoenix dactylifera* L. In addition, the variation in mineral composition of pinna samples from representative palms in commercial date gardens in the Coachella Valley of California was determined. Also, samples were obtained with a view to comparing the composition of pinnae from high-vigor and low-vigor palms of the same age growing in adjacent areas in the same garden. It was hoped that such data would aid in planning a program of soil fertility investigations.

Experimental Methods

In order to present an understandable description of the pinna sampling methods used with this relatively unfamiliar plant, it is advisable to describe briefly some aspects of its gross morphology and growth habits.

The date palm has a terminal bud or phyllophore, from which about 28 leaves per year emerge in a definite phyllotaxy (1). The leaf bases form a pattern of spirals which can be used in estimating the number of expanded leaves on the axis (3, 4), or the number of leaves inserted between two given leaves on the axis. From one-third to two-thirds of the leaves produced annually on mature bearing palms subtend inflorescences, depending on vigor and other factors. Leaves that emerge in the summer normally subtend inflorescences the following spring. The pinnate leaf of the date palm has a rachis 10 to 20 feet long, which usually bears between 150 and 250 pinnae. The proximal fourth of the rachis bears spines, and the transition from spine to laminar pinnae is rather abrupt with most varieties. These usually attain maximum size (area, dry weight) in the middle part of the distal three-fourths of the portion of the rachis bearing laminar pinnae. Leaves become fully elongated and expanded, that is, the activity of the basal meristem ceases 5 to 6 months after they first emerge from the bud. Green leaves may persist for 3 to 7 years, and usually range between 60 and 180 per palm, depending on moisture supply and other factors.

It was determined that there is a distinct gradient in mineral composition of pinnae related to position along the rachis. Pinnae from the distal portion of the rachis have a more "mature" composition (lower nitrogen, potassium and higher SiO_2 content, for example) than those from the basal portion. Pinnae from the center of the zone of laminar pinnae are intermediate in composition. The data presented in Table I indicate this relationship.

For the study of the relation of age of leaf to composition, pinna samples were obtained by removing 10 median pinnae (five from each side of the mid-point of the laminar-pinna-bearing portion of the rachis) from three consecutive leaves around the axis [refer to (1)],

TABLE I—THE DISTRIBUTION OF NITROGEN, POTASSIUM AND SILICON IN LAMINAR PINNAE IN RELATION TO POSITION ON THE RACHIS

Approximate Age of Leaves	Position on Rachis (Quarters)	Mean* Dry Weight Per Pinna (Grams)	Mean* Per Cent in Dry Matter		
			N	K	SiO_2
6 months	Distal	1.86	1.73	1.09	4.2
	Intermediate	2.70	1.70	1.23	3.4
	Intermediate	2.88	1.62	1.59	2.4
	Proximal	2.03	1.48	1.90	1.8
1 year	Distal	1.44	1.58	0.52	9.2
	Intermediate	2.41	1.68	0.51	8.8
	Intermediate	3.02	1.68	0.68	7.8
	Proximal	2.76	1.55	0.69	6.7
2½ years	Distal	1.30	1.31	0.26	17.4
	Intermediate	2.13	1.40	0.29	17.5
	Intermediate	2.52	1.42	0.33	17.0
	Proximal	2.24	1.34	0.30	16.2

*Mean of three samples from three leaves in each age group obtained from a mature Deglet Noor palm.

TABLE II—MINERAL COMPOSITION OF DEGLET NOOR DATE PINNAE FROM VARIOUS SECTIONS OF THE COACHELLA VALLEY (COLLECTED FEBRUARY–MARCH, 1942)

Section	Height of Palms (Feet)	Vigor	No. Leaves From Bud	Mean Dry Weight Per Pinna (Gms)	Percentage of Dry Matter						
					Soluble Ash	SiO_2	N	P	K	Ca	Mg
Rancho Mirage, Garden F	5–6	Low	16–20	2.80	4.52	2.93	1.89	0.115	1.64	0.56	0.16
			32–36	2.84	3.51	9.47	1.66	0.088	0.62	0.56	0.15
	10–12	High	16–20	2.74	4.65	2.58	1.89	0.121	1.64	0.57	0.16
			32–36	3.60	3.18	6.49	1.74	0.098	0.97	0.47	0.14
Indio Heights, Garden R	4–6	Low	16–20	2.64	3.90	2.88	1.81	0.116	1.06	0.48	0.17
			32–36	2.42	3.58	7.28	1.64	0.112	0.58	0.71	0.21
	16–17	High	16–20	3.47	3.74	2.42	1.82	0.109	1.24	0.35	0.14
			32–36	3.12	3.20	6.77	1.91	0.106	0.69	0.59	0.15
Indio Heights, U.S.D.G. Block 7	4–6	Low	16–20	2.35	3.58	2.68	1.70	0.113	1.12	0.44	0.16
			32–36	2.31	2.68	8.12	1.59	0.105	0.39	0.71	0.15
	12–16	High	16–20	2.87	4.55	3.21	1.83	0.110	1.46	0.60	0.19
			32–36	3.23	3.20	7.91	1.68	0.095	0.87	0.51	0.15
Oasis Garden MIR	16–18	High	16–20	3.11	3.80	2.29	1.73	0.114	1.49	0.33	0.15
			32–36	3.03	2.89	6.04	1.73	0.103	0.70	0.44	0.14
High School, Garden P	20–24	Very high	16–20	3.74	3.53	3.90	1.80	0.109	1.04	0.44	0.14
			32–36	2.99	2.68	9.39	1.81	0.099	0.55	0.52	0.11
	6–8	Very high	16–20	2.98	3.53	3.77	1.93	0.101	1.10	0.48	0.14
			32–36	2.99	2.68	7.08	1.74	0.095	0.74	0.44	0.14
High School, Garden J	10–15	Very high	16–20	2.88	4.24	3.44	1.99	0.127	1.40	0.48	0.14
			32–36	3.88	3.14	7.96	1.80	0.102	0.72	0.51	0.13
High School, Garden CVF	3–5	Very low	16–20	2.46	3.46	3.35	1.76	0.109	1.05	0.52	0.13
			32–36	2.33	3.17	6.94	1.64	0.108	0.54	0.79	0.18
	15–16	High	16–20	3.28	3.46	3.80	1.73	0.098	1.20	0.45	0.12
			32–36	2.72	2.90	8.18	1.69	0.094	0.64	0.60	0.12
Indian Wells, Garden WC	2–4	Very low	16–20	2.08	3.70	2.27	1.90	0.124	1.38	0.43	0.11
			32–36	2.06	2.55	7.21	1.78	0.104	0.54	0.57	0.13
	12–13	High	16–20	2.60	4.21	3.70	2.12	0.143	1.41	0.52	0.14
			32–36	2.67	2.79	7.24	2.01	0.121	0.64	0.49	0.16
Indian Wells, Garden HC	18–22	High	16–20	3.08	4.04	2.91	1.92	0.133	1.41	0.49	0.14
			32–36	3.46	3.17	6.05	1.85	0.127	0.81	0.52	0.14
	9–13	High	16–20	2.87	3.95	2.96	1.81	0.140	1.30	0.47	0.14
			32–36	2.53	3.10	5.80	1.71	0.181	0.77	0.52	0.15

making a total of 30 pinnae per sample. Beginning with the first three leaves[1] just emerging from the bud (called 0 in Figs. 1 and 2), groups of three consecutive leaves were sampled at intervals down the axis, so that the middle leaves of each group were spaced eight leaves apart in emergence sequence. This was done by locating the spiral formed by the bases of every eighth leaf in emergence sequence. The most prominent spiral of leaf bases with the Deglet Noor variety is formed by every thirteenth leaf on the axis, and is a nearly vertical column. The so-called eight spiral of leaf bases winds somewhat more sharply, and in the opposite direction from the thirteen spiral. Thus, by locating and marking an eight spiral of leaves on the palm, and using each step as the middle leaf of a group of three to be sampled, a series of samples spaced a definite number of leaves apart in emergence sequence were obtained. Of course, the time interval required for eight leaves to mature varies with season of emergence and vigor of palm. More leaves are produced by vigorous palms than by unthrifty ones. More leaves emerge in summer than in winter, and summer leaves grow more rapidly than winter leaves (1).

The pinna samples obtained for determining variation in composition among commercial gardens were obtained by collecting 30 pinnae in the manner described above. However, only two leaf positions on the axis were sampled. "Tophead" samples were obtained by locating the youngest fully expanded leaf having its lowermost spine pinnae just showing above the fiber. After marking this leaf, pinnae were obtained from it, and also from the next youngest leaf above it on the axis, and the next oldest below it. Usually these leaves are 6 to 7 months old, and are from 16 to 20 leaves below the youngest leaf having its first white pinnae just emerging above the fiber. "Midhead" samples were obtained in a similar manner, but two steps, or 16 leaves, below the center tophead leaf on the broad eight spiral. These leaves were situated about on the shoulder of the "head" on conical point of the fiber-sheathed axis. Midhead leaves are about 32 to 36 leaves from the youngest visible emerging leaf, and are a little over 1-year-old.

Samples obtained in this manner were wiped free of dust with a damp cloth, dried at 48 degrees C in a forced draft oven for 48 hours, then weighed, ground in a Wiley mill, and stored in light-tight containers. Total ammoniacal nitrogen was determined by the standard AAOAC method. Chlorophyll was determined by a modification of the method of Petering *et al* (5) previously described (9). The other mineral constituents were determined on a solution of the ash by the methods outlined by Reitemeier (6). Insoluble ash, called SiO_2, was determined by ignition and weighing of the acid-insoluble residue. Soluble ash was determined by difference from total ash.

Experimental Results

Leaf Age in Relation to Composition:—The data summarized in Figs. 1 and 2 were obtained by averaging the data from seven series

[1]The youngest leaf of this first group had pushed above the fiber sufficiently to get a sample of pinnae from the middle part of the rachis. These pinnae usually were etiolated and folded against the rachis.

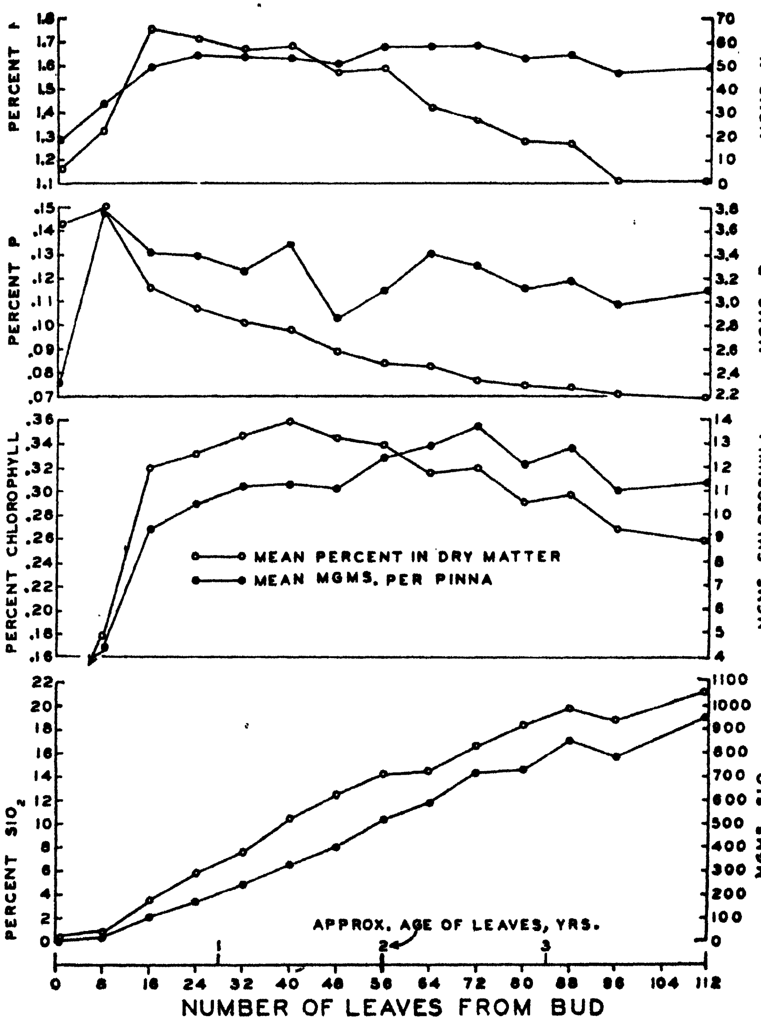

FIG. 1. The relation of silicon, chlorophyll, phosphorus, and nitrogen content to age of foliage for young bearing Deglet Noor palms at the United States Date Garden, Indio, California. The standard errors of the percentage means represented by the points 16 leaves from the bud are ±0.22, ±0.009, ±0.005, and ±0.06, respectively. For the points 32 leaves from the bud the respective values are ±0.29, ±0.020, ±0.003, and ±0.03.

of leaf samples obtained from seven normal, vigorous 7-year-old bearing Deglet Noor palms growing in Experimental Block 7 on the grounds of the United States Date Garden, Indio, California. The samples were collected February 23 to 26, 1942. Thus each point on the curves represents the mean of seven determinations in the great majority of cases. The data for each constituent were plotted sepa-

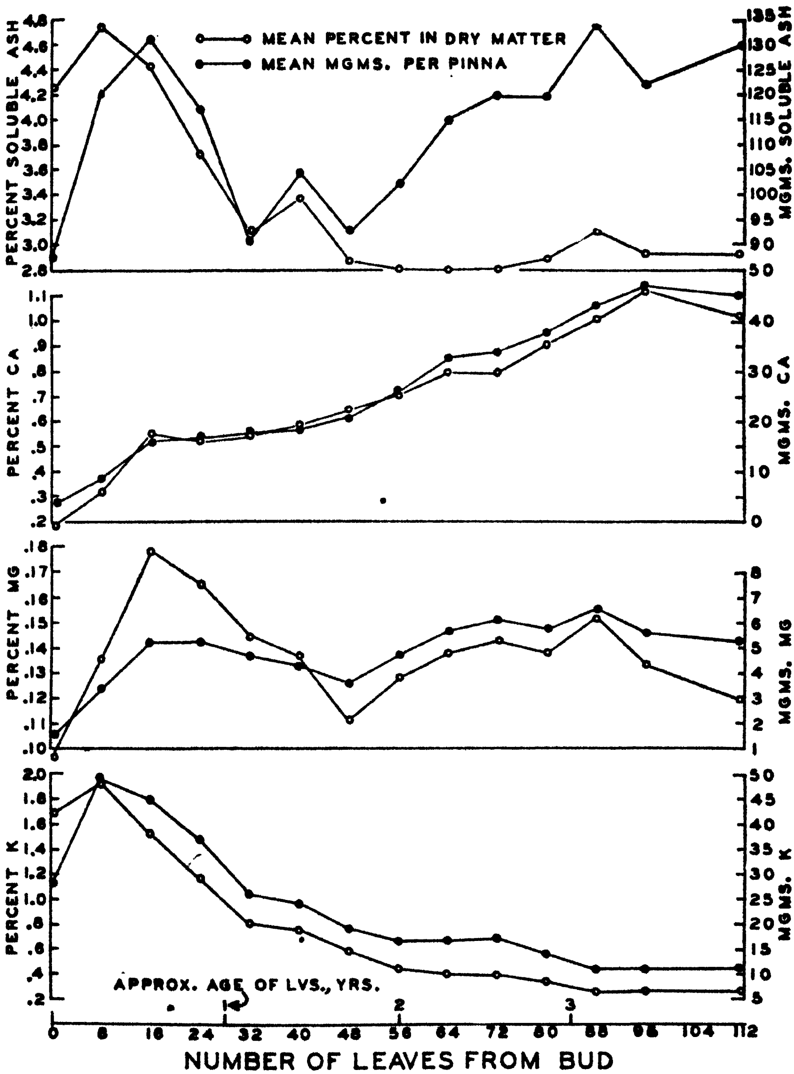

FIG. 2. The relation of potassium, magnesium, calcium, and soluble ash content to age of foliage for young bearing Deglet Noor palms at the United States Date Garden, Indio, California. The standard errors of the percentage means represented by the points 16 leaves from the bud are ±0.03, ±0.037, ±0.04, and ±0.12, respectively. For the points 32 leaves from the bud the values are ±0.03, ±0.007, ±0.05, and ±0.11, respectively.

rately for each palm, but all showed the same general trends shown by the means presented in Figs. 1 and 2. However, in the case of magnesium, the range of values averaged for each point was quite large, particularly in the zone at a distance of 40 or more leaves from the bud.

One of the most striking features of date leaf tissue is the high silicon concentration. In very young leaves the concentration is quite low, but there is a continuous and rapid increase with time so that leaves about 3 years old or more sometimes have more than 20 per cent of the dry weight, or 85 to 90 per cent of total ash, accounted for by acid-insoluble material. The curve showing the actual amount of SiO_2 per pinna indicates a continuous influx of this material into the leaf with time.

The chlorophyll content of pinnae just emerging from the bud is quite low; in fact, some of them may be almost white. The concentration increases rapidly as the leaf becomes fully expanded, then increases more slowly until the leaf is a little over a year old, then decreases slowly with increasing senility. However, the actual amount of chlorophyll per pinna increases somewhat until the leaf is nearly 3 years old, and then declines slowly.

Phosphorus is high in very young leaves, but the concentration drops very rapidly after the leaf becomes fully expanded. The actual amount of this element remains fairly constant as the leaf grows older, but perhaps there is a slight tendency for some to migrate out of the leaf.

The nitrogen concentration in date pinnae increases sharply until the leaf becomes fully expanded, then declines slowly but fairly continuously with age. On the other hand, the curve for actual amount indicates that the nitrogen content of a leaf remains fairly constant for a long period after it ceases basal growth.

The concentration of potassium in leaf tissue reaches a maximum before the leaf is fully expanded, then declines rapidly at first, then more slowly as the leaf becomes older. The data for milligrams of potassium per pinna indicate quite definitely that there is a corresponding initial rapid influx and subsequent rapid outward migration of leaf potassium.

The magnesium data obtained indicate that there is a relatively rapid initial increase in magnesium concentration until the leaf is fully expanded, then a rapid decline reaching a minimum somewhere between the first and second year, then another increase reaching a peak about the third year. The variability of the data precludes drawing any precise conclusions as to what happens to the actual amount of magnesium in the leaf after the initial rapid influx into the expanding leaf.

With calcium, as with silicon, there is a continuous increase in concentration with age. The curve for milligrams per pinna follows the concentration curve closely, and indicates a continuous accumulation of calcium within the leaf with time.

The soluble-ash concentration reaches a maximum before the leaf is fully expanded, decreases rapidly, then remains at a relatively low level. The actual amount of soluble ash in the leaf attains a maximum at the time the leaf is fully developed, then ash material migrates out of the leaf rapidly, reaching a minimum during the second year, then accumulates again during the third and fourth years. This second period of ash accumulation is probably due in part to the more rapid accumulation of calcium and magnesium than outward translocation of other elements.

In August 1942 comparable sets of samples were obtained from two of the same palms that were sampled in February at the United States Date Garden, and from two fully mature Deglet Noor palms in the Indian Wells district of the Coachella Valley. While there is suggestion of minor differences between the February and August samplings, and between the United States Date Garden and Indian Wells samples, the general trends were comparable to those presented in Figs. 1 and 2.

These data indicate that striking changes in some of the mineral constituents and chlorophyll occur in date palm leaves as they develop and grow old. With the exception of calcium and silicon, maximal concentrations of the major cations, as well as nitrogen, phosphorus, and chlorophyll, are reached just before or about the time the leaf becomes fully expanded. Apparently senescence of leaves is associated with accumulation of silicon and calcium.

The curves relating per cent of a constituent in dry matter to age of leaf do not always indicate the trend in actual quantity in a unit of tissue, such as a date pinna. The importance of sampling leaves of comparable age when attempting to compare the mineral composition of samples of date palm foliage from different localities or treatments is strongly emphasized. This requires a precise sampling procedure, and an intimate knowledge of the phyllotaxy of this plant.

Palm Vigor and Location in Relation to Composition:—The data summarized in Table II are typical of the range of variation found in mineral composition of foliage from representative vigorous commercial Deglet Noor plantings in the Coachella Valley. Analyses of samples from problem areas in many of these gardens also are presented. Usually six representative palms were selected in each age group or vigor condition found in a garden, and two samples of pinnae were taken from each palm, but in some cases only four or three palms were sampled in each group. The tophead (16 to 20 leaves from the bud) and midhead (32 to 36 leaves from the bud) samples obtained from each palm were analyzed separately for the constituents listed. Thus each figure presented in Table I is the mean of three to six determinations which agree fairly closely.

The variation in mineral constituents of vigorous palms among the date gardens in various localities, or between high-vigor and low-vigor palms in the same garden, is not striking when the difficulties of obtaining exactly comparable samples are considered. If all palms produced exactly the same number of leaves per year, the samples would all be from leaves of the same chronological age. Obviously this is not the case, particularly in the comparison of low-vigor and high-vigor palms. Thus some variation in composition might be expected due to this discrepancy in age among leaves occupying the same relative position on the axis of different palms.

These data suggest that there was no widespread, severe deficiency of any of the nutrient elements studied limiting the growth of Deglet Noor palms in the Coachella Valley at the time the study was made. Subsequent studies have shown the low vigor in some of the problem areas to be associated with inadequate moisture supply due to poor penetration or inadequate irrigation methods (2, 8). Unsatisfactory

growth in some very sandy spots is as yet not fully explained, but seems to be associated in some cases with a root condition suggesting a nematode problem.

The sampling of tophead and midhead leaf samples in the manner described above seems to be a satisfactory method of obtaining samples for comparative mineral analysis. The variation in chronological age among such samples, particularly when palms of different vigor levels are studied, seems to be the chief disadvantage; but no practical way of eliminating this difficulty suggests itself. Perhaps a better time to obtain samples would be in late fall, when the position of the leaves with respect to fruit bunches would be more readily ascertained. It might also be desirable to drop the midhead leaf sample one step of eight leaves farther down the axis, so as to place it more squarely in the middle of the current season's fruiting zone. There was some indication in the data from individual palms that mineral composition was influenced by whether or not the leaves sampled subtended a fruit stalk.

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Breakage of Tung Trees by Hurricane Winds in Relation to Variety, Pruning Method, and Crop

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ON THE morning of September 19, 1947, a hurricane passed over southern Louisiana and Mississippi. A wind velocity of 98 miles per hour was registered at New Orleans, 96 miles per hour at Baton Rouge, and estimated velocities ranging from 55 to 90 miles per hour occurred at other points within an area where there are more than 100,000 acres of tung orchards (2). The wood of tung *(Aleurites fordii)* is rather brash and susceptible to breakage. The 1947 tung crop was nearing maturity at the time of the storm and weight of fruit added to the strain from wind.

Test orchards comprising over 100 tung clones and a number of seedling varieties are located at several points within the area affected by the hurricane. Some of these clones are among the most promising yet found by the United States Tung Laboratories. Thus, an exceptional opportunity was afforded to evaluate resistance of different varieties to wind breakage and also the influence of different methods of training.

PLAN OF INVESTIGATION

The study was conducted in 14 experimental areas being used for varietal and pruning trials. A total of 8,650 trees, 3 to 7 years of age, all located within 40 to 70 miles to the northeast of the path of the hurricane center, were evaluated for wind damage.

In seven of these orchards the trees had been trained to two types, the vase form and the natural head. In developing the natural head, the nursery tree is cut to about an 8-inch stub at the time of planting and subsequently trained to one shoot, which usually branches without further pruning by midsummer or a little later, forming a head with fairly wide angles between trunk and branch. In training to vase form, the nursery tree is cut to 12 to 14 inches in height and all shoots are allowed to grow, forming a low, bushy type of head; and, as a rule the angles between branches and trunk are considerably narrower than those of the natural head tree. A total of 111 varieties were scored for damage; but data on only the 27 varieties concerning which the information is most complete, are reported in this paper.

In estimating the breakage, the trees were classified into 11 groups according to percentage of limbs lost, ranging from no damage in the first class to damage of 100 per cent in the last class, which denotes a tree broken down completely or so badly shattered as to be judged worthless. Thus, the average damage represents the approximate percentage of the bearing surface of the orchard that was lost. Each tree was examined individually both from the exterior of the tree and by close inspection of trunk and scaffold branches. No weight is given in this paper to damage from defoliation, abrasion of shoots, or fruit blown from the trees. The study has to do solely with loss of bearing

surface caused by branch or trunk breakage but includes damage from split and strained trunks and branches, and occasionally from trees being partially or wholly blown over. It appeared that when 50 or 60 per cent of the bearing surface was torn away the trees tended to go all to pieces. Hence, the intermediate classes tended to have low frequencies and those at either end of the range to have high frequencies, resulting distributions being either almost exactly the opposite of the so-called normal curve, or else very badly skewed. It was feared that conventional statistical treatment would be misleading, and the data have therefore been evaluated largely without statistical analysis. Means of large groups of the trees were much more normally distributed and analyses of variance could be used on such data when transformed to angles (1).

Results

Differences Between Orchards:—The estimates show that the damage varied widely between orchards and districts (Table I). Average damage in one block at the Mississippi Experimental Tung Farm, White Sand, Mississippi, was only 2.5 per cent, whereas in the neighboring Tonner orchard, damage was 11.6 per cent. Extreme damage

TABLE I—Breakage of Natural Head Tung Trees at Different Locations in Mississippi and Louisiana, by the Hurricane of September 19, 1947

Orchard	County or Parish	No. Trees Observed	Average Breakage (Per Cent)
Benedict	St. Tammany, La.	220	16.9
Dantzler	Harrison, Miss.	512	9.2
Experiment Station (A)	Pearl River, Miss.	27	8.1
Experiment Station (B)	Pearl River, Miss.	108	2.5
Experiment Station (C)	Pearl River, Miss.	220	4.6
Experiment Station (D)	Pearl River, Miss.	1,920	3.1
Green	Washington, La.	144	5.6
Louisiana Tung	St. Tammany, La.	50	19.4
Silverstein (A)	St. Tammany, La.	32	5.3
Silverstein (B)	St. Tammany, La.	1,088	24.6
Talcott	Pearl River, Miss.	512	10.7
Tonner	Pearl River, Miss.	1,024	11.6
White	Washington, La.	80	6.5
Total trees		5,937	—
Mean			9.9

was found in a block of 1,088 experimental trees in St. Tammany Parish, Louisiana, where 24.6 per cent of the bearing area was estimated as lost. Averaging the 5,937 natural head trees in the 13 orchards examined, damage ran some 9.9 per cent, rather more than in the average orchard of mature trees.

Differences Between Varieties:—From the first it became apparent that certain clones withstood the wind better than others. It is noted that in each of four orchards where a comparison can be made between the clones L–2 and L–14, the L–2 shows distinctly more breakage than the L–14 (Table II). The clone F–542 also appears inferior to L–14 in structural strength. Where comparisons can be made in the same orchard, F–542 seems on a par with or slightly superior to L–2.

TABLE II—BREAKAGE OF NATURAL HEAD TREES OF THREE PRODUCTIVE TUNG CLONES AT SEVERAL LOCATIONS IN MISSISSIPPI AND LOUISIANA BY THE SEPTEMBER HURRICANE OF 1947

Orchard	County or Parish	Variety (Per Cent)		
		F-542	L-2	L-14
Benedict	St. Tammany, La.	52.0	—	8.0
Dantzler	Harrison, Miss.	43.8	—	6.2
Experiment Station (A)	Pearl River, Miss.	6.7	25.0	1.0
Experiment Station (B)	Pearl River, Miss.	4.0	4.7	1.0
Green	Washington, La.	—	7.3	1.2
Louisiana Tung	St. Tammany, La.	43.8	—	28.8
Talcott	Pearl River, Miss.	4.5	—	13.0
Tonner	Pearl River, Miss.	17.5	18.0	5.5
Mean		24.6	13.8	8.1

Table III presents average experience with 22 clones and three seedling progenies trained by two methods and growing in three widely separated locations. There can be little doubt that such varieties as F-59, F-252, L-96, M-1, and L-51-Seedling, with an average damage of 4.7 per cent, withstood the hurricane winds more successfully than such other varieties as F-542, G-38, L-83, L-126, and M-67, with

TABLE III—INFLUENCE OF PRUNING, VARIETY, AND LOCATION ON BREAKAGE OF TUNG TREES BY SEPTEMBER HURRICANE OF 1947

Variety	Orchard							
	Benedict St. Tammany Parish, Louisiana		Dantzler-Harrison County, Mississippi		Talcott-Pearl River County, Mississippi		Average	
	Natural Head (Per Cent)	Vase Form (Per Cent)	Natural Head (Per Cent)	Vase Form (Per Cent)	Natural Head (Per Cent)	Vase Form (Per Cent)	Natural Head (Per Cent)	Vase Form (Per Cent)
A-4	1.0	24.0	5.6	19.4	3.4	8.8	3.3	17.4
F-9	23.0	6.0	8.8	2.5	5.0	11.7	12.3	6.7
F-59	2.0	15.0	0.0	0.0	0.0	0.0	0.7	5.0
F-179	15.0	25.0	2.5	20.0	0.0	24.3	5.8	23.1
F-184	18.8	55.0	13.8	12.5	0.0	10.0	10.9	25.8
F-252	1.0	1.0	0.0	0.0	0.0	11.2	0.3	4.1
F-542	52.0	70.0	43.8	50.0	4.8	22.2	33.5	47.4
F-546	19.0	56.0	0.0	25.0	0.0	0.0	6.3	27.0
F-555	10.0	20.0	15.6	0.6	2.0	19.1	9.2	13.2
F-573	5.0	13.0	0.0	26.2	0.0	6.2	1.7	15.1
G-38	57.5	37.0	18.8	73.8	14.5	0.0	30.3	36.9
G-40	3.2	36.0	2.5	0.0	12.5	10.0	6.1	15.3
G-46	6.0	21.0	5.0	11.2	10.0	18.0	7.0	16.7
G-53	43.0	21.0	25.0	45.0	28.8	2.5	32.3	22.8
L-14	8.0	16.0	6.2	12.5	13.2	19.4	9.1	16.0
L-83	19.0	32.6	20.0	43.8	0.0	0.0	13.0	25.5
L-96	6.0	3.0	0.0	12.5	0.0	17.5	2.0	11.0
L-120	9.0	18.0	13.8	7.5	0.0	30.5	7.6	18.7
L-126	31.0	30.0	12.5	31.2	42.0	0.0	28.5	20.4
M-1	3.0	4.0	6.2	0.0	30.0	3.8	13.1	2.6
M-22	25.0	33.0	3.8	27.5	25.0	5.0	17.9	21.8
M-67	46.2	14.0	21.2	32.5	66.7	5.0	44.7	17.2
McKee-S*	11.0	24.0	0.0	30.0	0.0	18.3	3.7	24.1
Buckley-S*	0.0	18.0	0.0	30.0	0.0	6.2	0.0	18.1
L-51-S*	9.0	2.0	0.0	5.0	5.0	3.3	4.7	3.4
Average by type head	16.9	23.8	9.0	20.7	10.5	10.1	12.2	18.2
Average by location	20.4		14.9		10.3		15.2	

Note: An analysis of transformed values for the data above gave an F value of 3.31 for differences due to varieties where 1.74 is required at .05 and 2.20 at .01. The F value for type of head was 12.04, where 4.03 is required at .05 and 7.17 at .01.

*S Seedling progeny produced from open pollinated seed of the original tree or in the case of the McKee, from second and third generation daughters of the original tree.

average damage of 29.7 per cent. An analysis of these data, transformed to angles, gave an F value for differences between varieties of 3.31, where a value of 1.74 is required at the .05 and 2.20 at the .01 levels of probability. Important differences undoubtedly exist among many other varieties scored at only two locations, but comparisons are less precise and hence the data are not shown here.

Differences Between Types of Head:—In the Benedict and Dantzler orchards, there was on the average nearly twice the structural damage to vase form trees as to natural head trees (Table III), and the F value for types of head was 12.04, where 4.03 and 7.17 are required, respectively, for .05 and .01 probability. This relation is quite consistent from orchard to orchard, although in the White planting in Washington Parish, Louisiana, and in the Talcott planting in Pearl River County, Mississippi, there seemed to be no important difference. It can also be pointed out that in the Stica planting in Pearl River County, Mississippi, consisting of 1,280 trees, all trained to vase form, the damage was only 5.2 per cent. It is to be noted that in both the Talcott and the Stica orchards the crops were rather light, a fact that doubtless greatly reduced breakage. There are exceptions where the vase form trees of certain clones did about as well as the natural head trees, or even better. When trained to vase form, the clone M–67 suffered an average breakage of only 17.2 per cent whereas when trained to natural

FIG. 1. Four-year-old vase form tung tree of G–40 variety, severely broken by hurricane of September 19, 1947, Folsom, Louisiana.

head, the average breakage was 44.7 per cent. On the other hand, the McKee seedlings seem to be exceptionally strong as a natural head tree and very weak when trained to vase form (Table IV). It had been observed previously that when trained to vase form the McKee seedlings tend to produce only a small number of primary branches, all arising from nearly the same point on the trunk. Considering all varieties, the natural head trees withstood the wind better than the vase form trees, especially when heavily laden.

TABLE IV—Breakage of Tung Trees of McKee Parentage by September Hurricane of 1947

Orchard	Clone or Seedling Progeny	Type of Head	
		Natural (Per Cent)	Vase Form (Per Cent)
Benedict	L-96*	6.0	3.0
	McKee Seedlings	11.0	24.0
Dantzler	L-96	0.0	12.5
	McKee No. 2*	2.5	40.0
	McKee Seedlings	0.0	30.0
Silverstein	McKee Seedlings	3.1	21.2
Talcott	L-96	0.0	17.5
	McKee Seedlings	0.0	18.3
Means		2.8	20.8

*L-96 and McKee No. 2 clones were propagated from selected first daughters of the original McKee tree; the seedlings were from open-pollinated seed from second and third generation daughters of the original tree.

Fig. 2. Five-year-old natural head McKee seedling tung trees practically uninjured by hurricane of September 19, 1947, Folsom, Louisiana.

Differences Due to Yield:—Data on weight of crop are available for each tree in the Benedict orchard. As is to be anticipated, trees bearing a heavy crop tended to suffer more breakage than those bearing a light crop (Table V). This tendency was much more marked in the case of the vase form than in the case of the natural head trees.

TABLE V—Relation of Weight of Crop to Estimated Hurricane Breakage, Benedict Orchard, St. Tammany Parish, Louisiana (1947)

Weight of Crop Per Tree (Pounds)	Type of Head			
	Natural		Vase Form	
	No. Trees	Average Estimate of Breakage (Per Cent)	No. Trees	Average Estimate of Breakage (Per Cent)
0–5	25	6.8	20	19.5
6–10	67	12.4	62	12.7
11–15	55	19.5	57	17.7
16–20	41	16.8	43	35.1
21–25	19	13.2	25	30.4
26–30	10	22.0	12	33.3
31–35	4	7.5	8	60.0
36–40	4	37.5	5	60.0
41–45	1	0.0	3	26.7
46–50	1	0.0	0	—

Discussion

There is much conjecture among those interested in tung growing as to the expected frequency of damaging hurricanes. Tannehill (3) states that 17 storms of hurricane intensity have struck the Gulf Coast, between the Perdido River in Florida and the Pearl River in Mississippi, in the 57-year period, 1879 to 1936, thus averaging one hurricane in every 3 to 4 years. These storms occur for the most part in August and September. He states further that "great" hurricanes have occurred in Louisiana in 1831, 1856, 1893, and 1915. The storm of September 1947 is generally acknowledged to have been the most severe since that of 1915. Storms less severe than hurricanes will occur almost every year and observations over the last 10 years have shown that even little local "twisters" often do much damage to tung orchards. Hence it seems important in choosing varieties of tung and determining methods of training, to take into consideration resistance to breakage by wind. The present tendency among tung orchardists is to fertilize and cultivate the trees intensively while they are young in order to obtain high yields at an early age. Such practices undoubtedly increase the hazard from wind breakage.

The investigation has shown that two of the most promising clones yet originated in the breeding program of the United States Field Tung Laboratories, namely, the L–2 and the F–542, have relatively weak wood and are likely to suffer serious damage from wind storms. Resistance to wind damage is one very important factor that must be considered with such others as productivity, frost resistance, and oil content, in evaluating a variety of tung for commercial purposes.

Summary and Conclusions

1. This study is based on estimates of breakage made on 8,650 individual tung trees of 3 to 7 years of age, within the area in southern

Louisiana and Mississippi affected by the hurricane of September 19, 1947.

2. The extent of breakage depended both on variety and on type of training. Most varieties suffered less when allowed to form a natural head than when pruned to a vase form. F–542 and L–2, two clones regarded as very promising in most respects, were badly broken. The McKee seedlings, when trained to a natural head, suffered very little breakage. Estimates are given for 24 other varieties.

3. Average breakage for all natural head trees of the age group studied was 9.9 per cent.

4. Breakage increased with weight of crop per tree, especially in orchards trained to vase form.

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A Taxonomic Survey of the Oriental Pears[1]

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More than 30 species of the genus Pyrus,[2] to which all pears belong, have been described. They are native to the Northern Hemisphere of the Old World. There are no pears native to either North or South America or to Australia.

From the geographical point of view, the species of Pyrus of the Old World can be divided into two native groups:

1. Oriental pears, which are native to Eastern Asia, including China and Japan. Their fruits are usually characterized by deciduous calyxes and non-fleshy pedicels, and are usually apple-shaped. *Pyrus Bretschneideri* and *P. pyrifolia* are the principal cultivated species.

2. Occidental pears, which are native to Eastern Europe and Southwestern Asia, including South Afghanistan, Transcaucasia and Asia Minor. Their fruits are usually characterized by persistent calyxes and fleshy pedicels, and are usually pyriform. *Pyrus communis* and *P. nivalis* are the principal cultivated species. Others, such as *P. salicifolia* Pall., *P. heterophylla* Rgl. et Schmald., *P. elaegrifolia* Pall., *P. syriaca* Boiss., *P. Bisseriana* Buhse., *P. Korshinskyi* Litw., and so on, according to the survey of Vavilov (11), grow wild in Caucasus and Turkistan.

The Occidental pears do not thrive in the Oriental region largely due to the difference in climate. The Oriental pears, especially the sand pears, require only a short chilling period to break the natural rest period. They are adapted to the warm, humid summers of central and southern China. The Occidental pears, on the other, require more severe chilling to break dormancy, and do not fruit well, especially in southern China. Another reason for the failure of European pears in China is their susceptibility to fire blight *(Bacillus amylovorus)*, which is more pronounced in a hot humid climate.

Based on the extensive collection of E. H. Wilson (8) in western China, A. Rehder (6) described 12 species, four varieties and one form of Chinese species of Pyrus. They are *Pyrus ussuriensis* Maxim., *P. ovoidea* Rehd., *P. Lindleyi* Rehd., *P. Bretschneideri* Rehd., *P. serotina Rehd.* (with *var. Stapfiana* Rehd., and *var. culta* Rehd.), *P. serrulata* Rehd., *P. phaeocarpa* Rehd. (with *f. globosa* Rehd.), *P. betulaefolia* Bunge, *P. Calleryana* Decaisne (with *var. dimorphophylla* (Mak.) Koidzumi), *P. kolupana* Schneid., *P. Koehnei* Schneid., and *P. pashia* Hamilton apud Don, (with *var. kumaoni* Stapf.). All these species can be found in the wild state.

The old species name, *Pyrus sinensis* Lindl., was considered by C. S. Sargent and A. Rehder (6) to include all the cultivated forms

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[1]The author is much indebted to Dr. H. B. Tukey for his valuable criticism, and to Mr. V. J. Fisher for his help in the prepartion of the manuscript.

[2]The genus name Pyrus is used here in its narrow sense, that is excluding Malus. However some authors, such as L. H. Bailey, uses Pyrus to include both Pyrus, the pears, and Malus, the apples and crabs. Transfers of species and varieties from Malus to Pyrus, or vice versa, are still in progress (M. L. Fernald. Rhodora. 49: 229–233. 1947).

of pears in eastern Asia. Thus it can no longer be used as an independent species. Rehder, who assigned the name, *P. serotina* Rehder (6) to the sand pear, now concludes that it is the same as the older name, *P. pyrifolia* (Burm.) Nakai (4).

Up to the present time about eight species of Asiatic origin are considered to be of pomological value, either as rootstocks or for their fruits. They can be separated by the following key:

A. Fruit large, brown or yellow; cultivated for fruit.
  B. Fruit with persistent calyx, greenish yellow; leaves setosely serrate .... *Pyrus ussuriensis.*
  BB. Fruit with deciduous or partly deciduous calyx, brown or yellow.
    C. Fruit yellow; leaves broad-cuneate at base, sharply serrate with accuminate setose teeth...*Pyrus Bretschneideri.*
    CC. Fruit usually brown; leaves round or subcordate, setosely serrate .... *Pyrus pyrifolia.*

AA. Fruit small, usually less than 3 cm in diameter, brown, rarely yellow; wild or cultivated as rootstocks.
  B. Leaves dentate or sharply serrate.
    C. Leaves serrulate with acute teeth.......*Pyrus serrulata.*
    CC. Leaves dentate-serrate, with more or less spreading teeth.
      D. Leaves glabrous, styles 2 to 4, rarely 2; fruit subglobose or pyriform, 1.5 to 2.5 cm long............ *Pyrus phaeocarpa.*
      DD. Leaves pubescent, 4 to 7 cm long; styles 2 or 3; fruit subglobose, about 1 cm in diameter................ *Pyrus betulaefolia.*
  BB. Leaves crenate.
    C. Styles 3 to 5; leaves ovate to oblong......*Pyrus pashia.*
    CC. Styles 2 to 3; leaves orbicular-ovate to oblong-ovate.... *Pyrus calleryana.*

Among the species given in the above key, only three are cultivated as commercial fruit trees in China and Japan. They are *Pyrus pyrifolia* Nakai (Syn. *P. serotina* Rehd.), the sand pear; *P. Bretschneideri* Rehd., the Chinese white pear; and *P. ussuriensis* Maxim., the Ussurian pear. The other species are native to central and western China. Their trees are large and vigorous and resistant to fire blight, but their fruits are so small, hard and acid that they have no edible value. Hence they are used only as breeding materials and as root stocks, principally for their resistance to fire blight.

The geographical distribution of the three cultivated species in China is quite distinct. The sand pear (*Pyrus pyrifolia* Nakai) is most widely distributed, extending over the entire central and southern region of China, as well as in Formosa and Japan. In the Yangtze Plain, Szechuan Basin, Si-Kiang Valley and the Southwestern Uplands, sand pears are the most popular fruits. Starting from the Hwei Valley and the Tsingling Range, corresponding to the 750-mm annual rainfall line, the sand pear extends south to the Pacific Coast, where the temperature and humidity are higher, the rainfall is greater, and the soil is

mostly of the lateritic type. The area of distribution, therefore, is quite similar to that of rice and citrus fruits (9).

The sand pear is not high in quality. The fruit is heavily russeted and commonly apple-shaped. The flesh contains many grit cells, and has little aroma. However, it is rich in sugar, high in water content, and has a refreshing, sweet taste and a crisp texture.

As for the classification of varieties, Rehder (7) has mentioned one form, *f. Stapfiana* (Rehd.) Rehd., which is characterized by its pyriform fruit, and *var. culta* (Mak.) Nakai, which is characterized by its broader leaves and fruits. Great variation of this species has been found in the habit of branching, the shape and margin of the leaves and the color and shape of the fruits. Hundreds of cultivated varieties have been named by the local growers. Some of the popular ones are Pei-Chang-Li and Wong-Chang-Li in Chekiang, Chang-Chee-Li in Szechuan, Chao-Tung-Li in Yunnan, Sheu-Li in Fukien, Sha-Tung-Li in Kwangsi, and Thom-Shui-Sha-Li in Kwang-tung. From the pomological point of view the writer would divide them into four main groups:

A. Skin yellowish brown to deep brown.
  A_1. Fruit apple-shaped .... group I.
  A_2. Fruit oblong-ovate to pyriform .... group II.
B. Skin yellowish green to green.
  B_1. Fruit apple-shaped .... group III.
  B_2. Fruit oblong-ovate to pyriform .... group IV.

So far as quality of fruit is concerned, the best of the Oriental pears is not the sand pear but the Chinese white pear (*Pyrus Bretschneideri* Rehd.). The region favorable to this species is the North China Plain and the Sungtung Peninsula. It extends from the Hwei Valley and the Tsingling Range north to the Great Wall and the 400-mm annual rainfall line. Its geographical distribution, therefore, corresponds to the "Wangho pomaceous fruit region" (9), where the weather is colder and drier, rainfall is less (average 700 mm or less), and the soil is mostly of gray-brown podzolic type. It is also grown in the Northeastern Provinces (Manchuria), especially the Liaotung Peninsula and the Manchurian Plain. However, it is not so common as the Ussurian pear in that region.

The white pear and sand pear are about equally desirable from the standpoint of their high sugar and water content. However, the white pear is more desirable from the standpoint of its smaller number of stone cells, and its finer texture of flesh. The fruits, which may be apple-shaped or pyriform, are usually yellowish green in skin color and occasionally brown. Peiping Pei-Li, Tang-Hsien-Li, Tientsien Yueh-Li, Sungtung Laiyoung Chi-Li are some of the well known varieties.

Ussurian pear (*Pyrus ussuriensis* Maxim.) is native to and commonly cultivated in the Northeastern Provinces of China. This is the hardiest among the Oriental group. The tree is very resistant to fire blight; and the fruit is soft-fleshed and not excessively gritty. It is distributed over the Manchurian Plain and the Liao Valley, where for 5

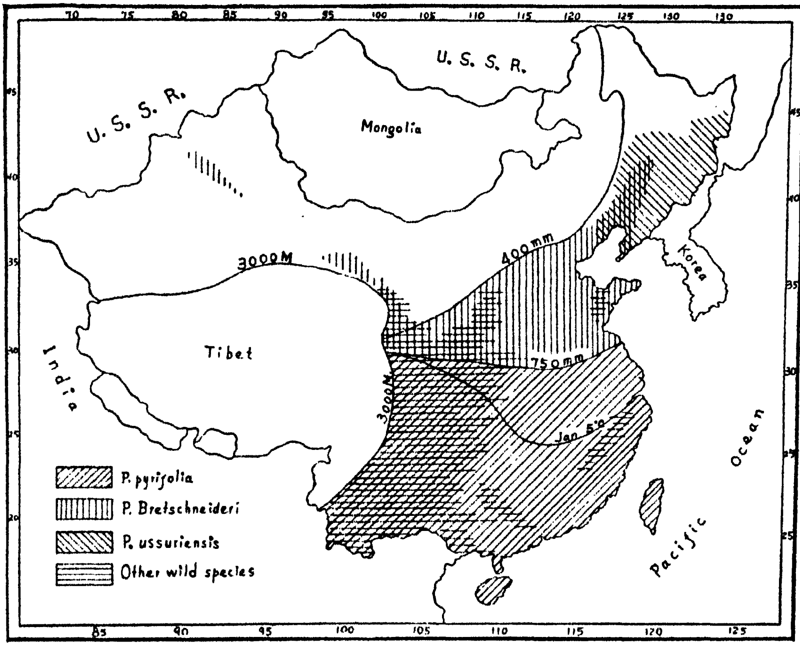

FIG. 1. The distribution of pears in China.

months of the year the temperatures average below freezing and the growing season is less than 150 days. Two varieties, *var. ovoidea* (Rehd.) Rehd., and *var. hondoensis* (Kikuchi and Nakai) Rehd., have been described. The wild forms still can be found along the eastern Manchurian Hills, and in North Korea.

Since the whole group of pears, both East and West, wild and cultivated, are of the same chromosome number (n = 17) (1, 4), interspecific crossing is quite possible. LeConte, *Pyrus Lecontei* Rehd. (*P. communis* x *P. pyrifolia*), which is characterized by serrulate or crenate-serrulate leaves, and yellow fruits with persistent calyx, is a good example of an interspecific hybrid. The crossing of the sand pear and the Chinese white pear has also been found successful in Central China.

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Specific Gravity and Percentage of Kernel as Criteria of Filling of Pecan Nuts

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IN grading pecan nuts grown under different cultural treatments the writers found it difficult to evaluate nut quality accurately enough to make comparisons without much tedious and time-consuming work. The percentage of kernel was probably the best criterion for use in comparing the kernel development of nuts within a variety, but in order to determine percentage of kernel the nuts had to be shelled. Sitton (1) suggested that specific gravity might be more accurate than percentage of kernel in evaluating the quality of nuts, because nuts with light shells might have as high percentage of kernel as nuts with heavy shells even though the kernels were not so well developed. Thus, it was desirable to determine some of the relationships of specific gravity of pecan nuts to their kernel development and quality. Experiments along this line were begun in the autumn of 1936 and extended through 1939. The results are reported herein.

CHANGES IN SPECIFIC GRAVITY OF NUTS UPON DRYING

In the fall of 1936 nuts of the five varieties, Burkett, Halbert, Mahan, Western, and Success, were harvested from orchards near Brownwood, Cross Plains, and May, Texas. The nuts were brought to the laboratory and stored in open paper bags until specific gravity determinations could be made. The Halbert nuts were from trees that had been partially defoliated by insects in the early autumn and these were brought to the laboratory in the shuck; consequently they did not dry during storage as rapidly as did the nuts of the other varieties.

Specific gravity determinations at first were made on individual nuts in a specific gravity bottle by displacement of distilled water, but in some cases an Erlenmeyer flask was used which accommodated samples of 10 to 25 nuts at one time. After specific gravity determinations were made the nuts were dried to constant weight in an electric drying oven at approximately 35 degrees C, and then specific gravity determinations were made on the dry nuts. The loss of moisture from each lot and the changes in specific gravity are shown in Table I.

On the whole the specific gravity of the nuts decreased upon drying at 35 degrees C, if the moisture loss was about 10 per cent or more, but increased upon drying if the moisture loss was less. Exceptions occurred in the Western variety and in two lots of the Mahan. With the higher initial percentages of moisture the loss of weight was relatively greater than that of the volume and consequently the specific gravity of the nuts decreased, while with the lower initial moisture content the reverse was true.

Changes in the Specific Gravity of Nuts With Maturity and Upon Drying

Since the data obtained in 1936 (Table I) indicated that the specific gravity of pecan nuts changes as they dry out, it was desired to determine more closely the effect of varying moisture content on the specific gravity of nuts. Accordingly, experiments were begun in the fall of 1937 in which comparable lots of nuts were harvested at intervals during the ripening period, and determinations of specific gravity and

TABLE I—Effect of Moisture Loss on the Specific Gravity of Pecan Nuts When Dried at 35 Degrees C (1936)

Variety.	Nuts (Number)	Moisture Lost (Per Cent)	Average Specific Gravity		Change in Specific Gravity (Per Cent)
			Before Drying	After Drying	
Burkett*.........	25	4.1	0.815	0.826 +	1.35
Burkett*.........	25	4.5	0.802	0.815 +	1.62
Burkett*.........	25	5.6	0.803	0.812 +	1.12
Burkett*.........	10	7.7	0.812	0.830 +	2.34
Burkett*.........	10	10.9	0.829	0.821 –	0.84
Burkett†.........	10	14.9	0.901	0.780 –	13.4
Burkett†.........	20	27.8	0.654	0.533 –	18.5
Halbert†.........	25	12.3	0.622	0.579 –	6.91
Halbert**........	17	12.5	0.465	0.446 –	4.08
Halbert*.........	22	13.5	0.820	0.777 –	5.24
Halbert†.........	24	15.1	0.695	0.659 –	5.18
Halbert†.........	25	17.5	0.688	0.634 –	7.85
Halbert†.........	10	21.2	0.778	0.646 –	17.0
Halbert†.........	25	24.0	0.692	0.583 –	15.7
Mahan*..........	15	4.6	0.821	0.824 +	0.36
Mahan**.........	14	5.3	0.657	0.652 –	0.76
Mahan*..........	10	8.2	0.824	0.830 +	0.73
Mahan*..........	10	9.1	0.849	0.846 –	0.35
Schley*.........	10	8.4	0.866	0.873 +	0.81
Western*........	10	6.8	0.828	0.819 –	1.09
Success*.........	10	6.4	0.820	0.839 +	2.32
Success*.........	10	7.5	0.805	0.809 +	0.50

*Well filled nuts.
**Poorly filled nuts.
†About one-third of nuts very poorly filled; others with fair filling.

of the percentage of kernel were made at various moisture levels as the nuts dried. Samples of 20 nuts of average maturity at each date were used for each lot, and the samples were collected at approximately weekly intervals for five to eight consecutive sampling dates, depending upon how rapidly the nuts matured. For the first sampling date six comparable lots were selected and weighed. One lot was immediately placed in an oven at 35 degrees C, and dried to constant weight and the moisture loss was calculated as percentage of original fresh weight. This percentage was taken as representative of the moisture in each of the six lots at the date of sampling.

The specific gravity of each of the other five lots was determined immediately, and one lot was shelled and the percentage of kernel was calculated. The shells and kernels were stored separately in open containers at room temperature and were reweighed at intervals so as to follow the changes in percentage of kernel and shell as drying proceeded, and to determine the relative losses of moisture from shells and kernels. The remaining four lots were stored in open paper bags at room temperature, and when they had lost approximately one-fourth of their moisture, as indicated by the loss in weight compared

with the loss of moisture from the oven-dried lot, the specific gravity of each lot was determined. One lot was shelled and the percentage of kernel was calculated, the shells and kernels being stored in open containers at room temperature for further determinations as above. The remaining three lots were subjected to the same procedure as above, one lot being shelled at the end of each drying period. At the end of the last drying period the last lot was air-dry at room temperature. The amount of moisture remaining in each lot at this time was calculated from the amount lost and the amount present at the beginning of the experiment. The percentage of moisture present in each lot at each date of specific gravity determination was also calculated.

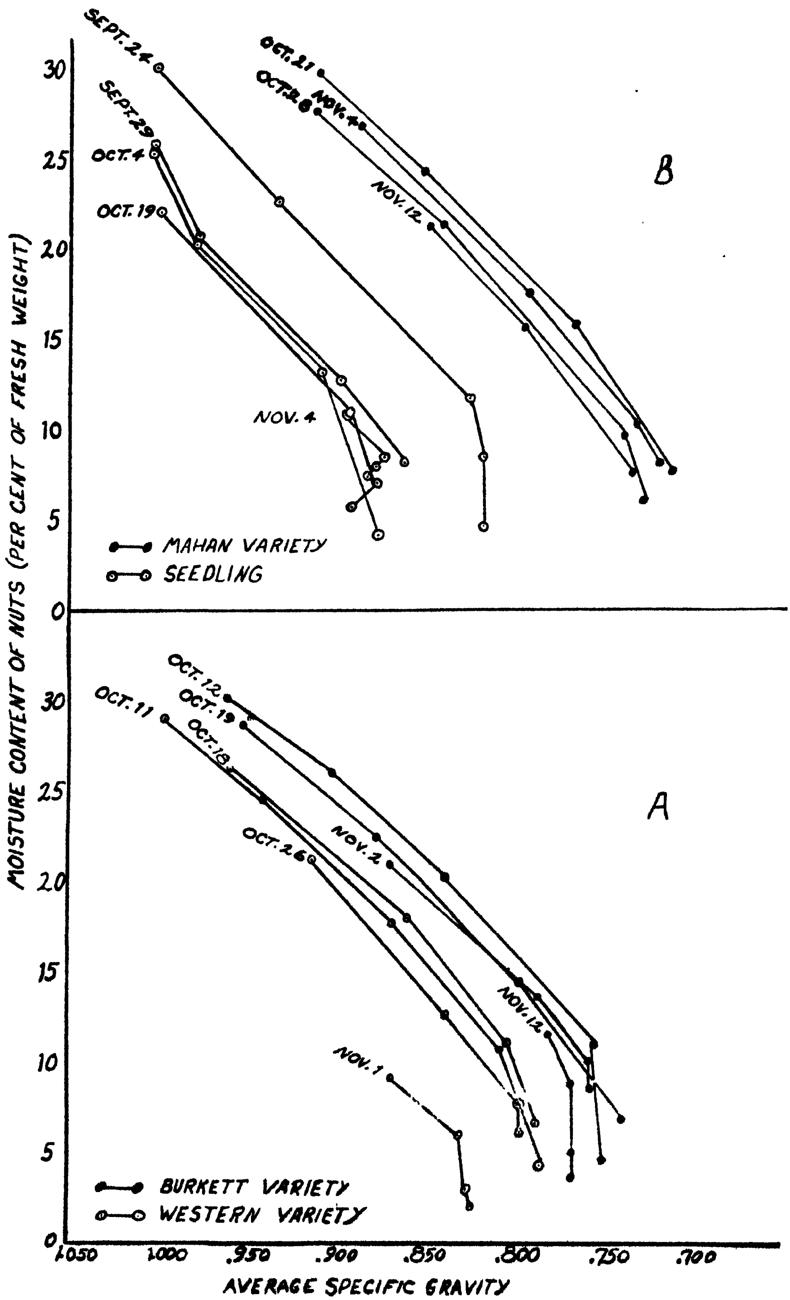
Five lots of nuts were harvested at each sampling date after the initial harvest, and were handled in the same manner as the initial samples. Nuts of Burkett, Mahan, and Western varieties together with those of two seedlings were used in the experiment. The changes in specific gravity and moisture are presented in Fig. 1; data on loss of moisture from shells and kernels will be presented later.

It is interesting to note that the moisture loss during ripening of nuts on the tree was relatively small until late in the harvest season. Thus, the moisture content and consequent specific gravity remained relatively high for nuts on the tree until they were fully ripe and the shucks had opened.

The specific gravity decreased rapidly as the nuts dried out after harvest until the moisture content was reduced to around 10 per cent, after which there was relatively little, if any, further decrease in specific gravity with further drying at 35 degrees C. In fact the specific gravity increased with drying at the lower moisture levels in some cases, and perhaps this would have occurred in all cases if the nuts had been dried sufficiently.

In 1939 experiments were devised to determine more fully the relationship and specific gravity of pecan nuts, especially at the lower moisture levels.

Comparable lots of nuts of the Burkett and Western varieties and of two seedlings were harvested when they were first fully mature, except that those of the Western variety were slightly short of full maturity. The nuts were divided into 20 or 25 comparable lots of 20 nuts each, and five randomly selected lots were placed in each of four or five groups, and all lots weighed. The specific gravity was determined immediately for each of the five lots of one group, after which these lots were placed in a vacuum oven and dried to constant weight at a temperature of 50 to 55 degrees C and 28.5 inches of mercury. The nuts in the other groups of lots were dried at different rates, being kept part time in open containers, in desiccators over concentrated sulfuric acid, or in drying ovens at approximately 35 degrees C. The lots in all groups were weighed frequently and the specific gravity was determined at various intervals as the nuts lost weight in drying. Finally all lots in all groups were dried to constant weight in air ovens at 95 degrees C, and the original moisture content of each lot was calculated as well as the amount present at each date the specific gravity was determined. The data are presented in Fig. 2.


SEPT. 24
OCT. 21
NOV. 4
OCT. 28
SEPT. 29
OCT. 4
OCT. 19
NOV. 12
B
NOV. 4
MAHAN VARIETY
SEEDLING
OCT. 12
OCT. 19
OCT. 11
OCT. 18
OCT. 26
NOV. 2
A
NOV. 12
NOV. 1
BURKETT VARIETY
WESTERN VARIETY
MOISTURE CONTENT OF NUTS (PER CENT OF FRESH WEIGHT)
AVERAGE SPECIFIC GRAVITY
1.050
1.000
.950
.900
.850
.800
.750
.700
0
5
10
15
20
25
30

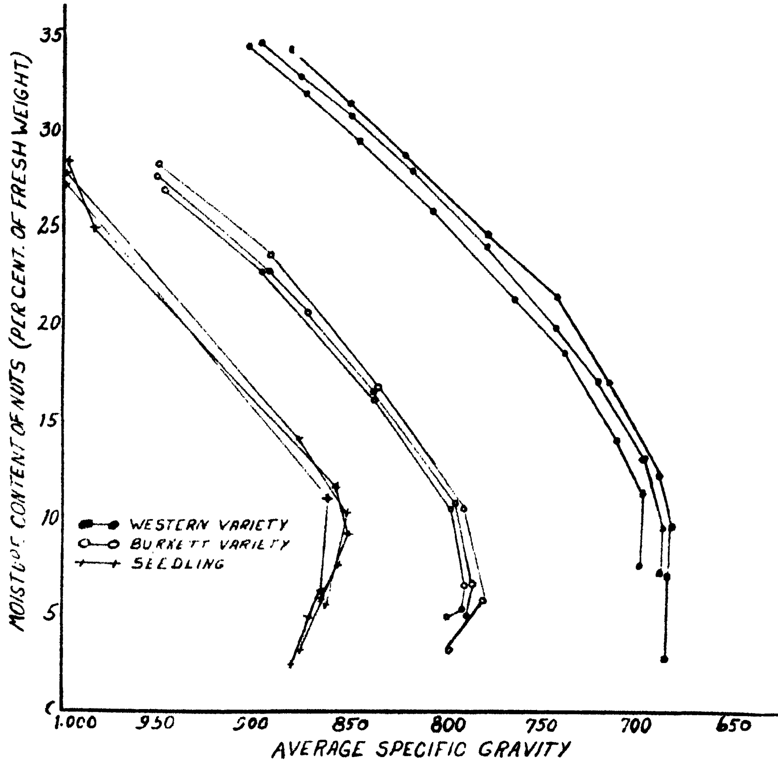


FIG. 2. Changes in specific gravity of pecan nuts with loss of moisture. Western, Burkett, and seedling varieties (1939). Each curve is based on data from five lots of 20 nuts each, and three methods of drying are represented. Moisture was calculated as the percentage of fresh weight for each point on the curves. The first determination is uppermost in each curve.

These data confirm those of the 1937 experiments in that the specific gravity of green mature nuts decreased rapidly with drying until the moisture content was reduced to around 10 per cent. Within the moisture range of 5 to 10 per cent the specific gravity of the nuts reached the minimum, and then increased upon further drying.

The volume of the nuts decreased gradually as drying proceeded until the moisture was reduced to 10 to 15 per cent, then it decreased rapidly with further drying until finally the relative decrease in volume was greater than that of the weight. At this point the specific gravity began to increase with further drying. These relationships are shown by the curve in Fig. 3 for the Western variety which is typical of those for the other varieties used.

FIG. 1. Changes in specific gravity of pecan nuts with maturity and with loss of moisture. A, Burkett and Western varieties; B, Mahan and seedling varieties. Each curve is based on the average specific gravity and moisture content of 20 nuts. Date of harvest, or of first determination, is indicated at the top of each curve. Later determinations were made periodically as the nuts dried (see text).

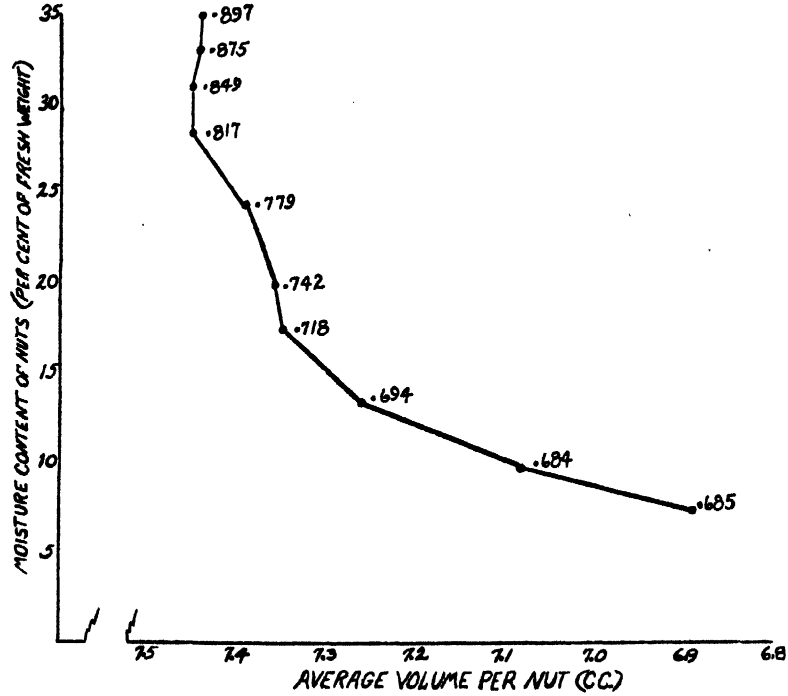


FIG. 3. Changes in the volume of pecan nuts with varying moisture content (Western variety, 1939). The curve is based on the average volume and moisture content of five lots of 20 nuts each. The average specific gravity of the nuts is indicated at each point on the curve, the first determination being uppermost.

Changes in Specific Gravity of Dry Nuts After Soaking in Water

Since the specific gravity of freshly harvested pecan nuts with relatively high moisture content decreased with loss of moisture until a relatively low moisture content was reached and then increased with further drying, it is desirable to determine if the process is reversible in the dry nuts.

Lots of 10 nuts each, varying from low to high specific gravity, were selected from the Stuart, Schley, and Success varieties. The nuts were selected from orchard-run samples that had been stored in the laboratory at room temperature since harvest and were air-dry. The specific gravity of each individual nut was determined by the method of Waugh (4) and then each lot was submerged in water at room temperature. Specific gravity determinations were made at the end of 1-hour intervals for four consecutive periods of soaking. Then the nuts were soaked for 2-hour intervals for two consecutive periods, and then for 16 hours more, specific gravity determinations being made at the end of each interval. The results are shown in Fig. 4.

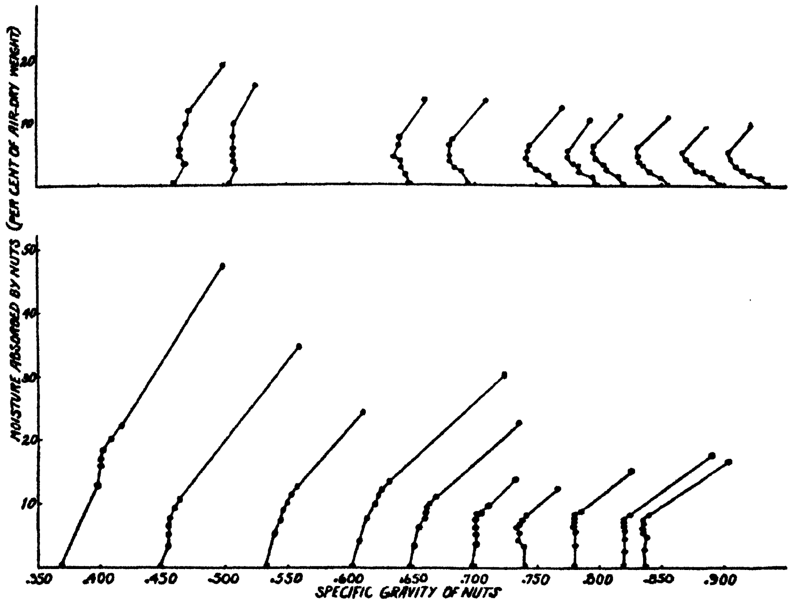


FIG. 4. Changes in the specific gravity of individual air-dry pecan nuts with absorption of moisture. Above, ten nuts of the Stuart variety; below, ten of the Success variety (1937). The first determination is lowermost in each curve.

The chart for the Schley variety is omitted since it was nearly identical with that for the Stuart.

The curves for the Stuart variety are very similar to those for the varieties that were dried immediately after harvest in 1937 and 1939 (Figs. 1 and 2). It is noted that in both Stuart and Success varieties the poorly filled nuts (nuts of low specific gravity) absorbed considerably higher percentages of moisture during soaking than did nuts of higher specific gravity. Conversely, poorly filled nuts of the Halbert, Burkett, and Mahan varieties lost greater percentages of moisture in drying than did the better filled nuts of the same varieties (see Table I). Because of the smaller amounts of kernel in the poorly filled nuts the greater proportion of moisture absorbed or lost from the nuts is necessarily absorbed, or lost, by the shells.

On the whole the air-dry nuts of the Success variety absorbed higher percentages of moisture than did those of the Schley and Stuart varieties during 24 hours of soaking. Thus, the total specific gravity changes were generally greater in nuts of the Success variety for the entire period of soaking, but on the whole they were somewhat less in Success nuts of high specific gravity during the first 8 hours of soaking than in Stuart nuts of comparable specific gravity.

It is interesting to note that the specific gravity of nuts of the Success variety did not decrease during the first few hours of soaking as did that of Stuart nuts. This indicates that at low moisture levels the

volume of Success nuts varies less with a given change in moisture content than does that of Stuart nuts.

Proportionate Loss of Moisture From Shells and Kernels of Pecan Nuts Dried at 35 Degrees C, and its Effect on the Percentage of Kernel:—Since the specific gravity of freshly harvested nuts decreased materially during the drying process until the moisture content reached fairly low levels, it was desirable to determine the effect of drying on the percentage of kernel, or, in other words, the proportionate loss of moisture from kernels and shells. Some nuts of the Halbert variety used in 1936 specific gravity experiments were shelled after the specific gravity had been determined, and the shells and kernels of each nut were weighed and then were dried separately at 35 degrees C, and reweighed. From the weights in each case the percentages of kernel were calculated, as well as the percentages of moisture lost from the shells and from the kernels. During the 1937 season some nuts of each variety used in specific gravity experiments were shelled and the weights of shells and kernels recorded, after which the shells and kernels were allowed to dry at room temperature, being reweighed at intervals. The percentages of kernel and moisture losses for each interval were calculated from the weights. The data for the two seasons are presented in Tables II and III, respectively.

TABLE II—Moisture Loss from Shells and Kernels of Pecan Nuts When Dried at 35 Degrees C, and Its Effect on the Percentage of Kernel (Halbert Variety, 1936)

Number of Nuts	Specific Gravity Range	Specific Gravity of Whole Nut Before Drying (Average)	Moisture Loss From: Kernel (Per Cent)	Moisture Loss From: Shell (Per Cent)	Proportion of Kernel by Weight: Before Drying (Per Cent)	Proportion of Kernel by Weight: After Drying (Per Cent)	Increase in Proportion of Kernel (Per Cent)
6	0.400–0.499	0.432	14.70	18.50	8.71	9.10	4.47
6	0.600–0.699	0.667	6.35	11.71	43.81	45.43	3.69
7	0.700–0.799	0.762	6.15	13.92	50.70	52.87	4.28
19	0.800–0.899	0.869	3.79	12.86	56.04	58.57	4.51
9	0.900–0.925	0.909	3.58	13.11	58.55	61.10	4.35

The data in Table II are grouped for nuts in different specific gravity ranges, and show that the percentage of moisture lost in drying was greater in both shells and kernels of very poorly filled nuts than in those with better kernel development. The percentage of moisture lost from kernels tended to decrease as the kernel development increased, but was more nearly constant for the shells of nuts that contained as much as 40 per cent or more of kernel. The percentage of kernel increased in all cases in these Halbert nuts when they were dried due to the fact that the greater proportion of the moisture was lost from the shells.

The data in Table III represent nuts of relatively high specific gravity in all cases, and show the trend of changes in percentage of kernel as drying proceeded. It is noted that the percentage of kernel decreased somewhat as the moisture decreased until a fairly low percentage of moisture was reached, and then tended to increase. In nuts of the Burkett and Western varieties there was an over-all slight de-

crease in the percentages of kernel during drying at room temperature, whereas in those of the seedling there was a slight increase. As a rule it appears that only a relatively small change in percentage of kernel takes place when pecan nuts of around 25 per cent moisture content are dried at room temperature. Thus, it appears that the percentage of kernel is more reliable as a criterion for grading uncured nuts than is the specific gravity.

TABLE III—RELATIVE RATE OF DRYING OF SHELLS AND KERNELS OF SHELLED PECAN NUTS AND ITS EFFECT ON THE PERCENTAGE OF KERNEL (BURKETT, WESTERN, AND SEEDLING VARIETIES, 1937)

Date	Moisture in Shells + Kernels (Per Cent of Fresh Weight)	Moisture Lost During Each Interval From: Shells (Per Cent)*	Kernel (Per Cent)*	Proportion of Kernels (Per Cent)
		Burkett Variety		
Oct 12	30.20	0.00	0.00	55.8
Oct 13	22.40	10.77	10.00	56.0
Oct 15	12.38	9.15	12.70	55.0
Oct 18	5.92	3.42	9.67	53.4
Dec 10	3.40	4.22	1.19	54.2
		Western Variety		
Oct 11	26.90	0.00	0.00	57.9
Oct 12	18.10	11.70	10.11	58.2
Oct 14	9.22	6.85	11.82	56.9
Oct 16	4.73	3.84	5.46	56.5
Dec 9	3.51	2.33	0.52	57.0
		Seedling Variety 5320		
Sep 24	25.31	0.00	0.00	52.4
Sep 25	14.00	11.40	14.40	51.5
Sep 27	8.49	5.10	6.90	51.0
Sep 28	7.45	1.80	0.50	51.3
Sep 30	2.42	8.60	1.80	53.5

*Per cent of fresh weight at beginning of interval.

Shell-Weight Per Unit Volume of Nut:—Since the specific gravity of a nut is its weight per unit volume compared with the weight of an equal volume of a standard (water in this case), the shell-weight (grams) per unit volume (cubic centimeters) on the same basis would represent the specific gravity of the nut if it contained no kernel whatsoever. If the shell-weight per unit volume were constant for a variety it would serve as a criterion for calculating the percentage of kernel directly from the specific gravity, and thus would avoid the laborious and tedious task of shelling the nuts for this purpose.

In order to determine the variability of the shell-weight per unit volume of nut in a variety, the shell-weight per cubic centimeter of volume was determined for various varieties by shelling the nuts after the specific gravity was determined and weighing the shells, then calculating the shell-weight per cubic centimeter volume of nut. Since the shell-weight (grams) per cubic centimeter of volume of the whole nut is equivalent to the specific gravity of the nut without any kernel, then if this volume be subtracted from the specific gravity of the nut the remainder is the kernel-weight per cubic centimeter of volume of the whole nut. If the latter be divided by the specific gravity of the nut

and the quotient multiplied by 100, the result equals the percentage of kernel contained in the nut.

The standard deviation of the shell-weight per cubic centimeter volume of nut is given in Table IV for samples of the Burkett, Sovereign, and Stuart varieties grown in different localities in 1936; and the average ratios of shell-weight in grams to volume in cubic centimeters for nuts of the Burkett, Success, and Schley varieties in various specific gravity ranges, are presented in Figs. 5, 6, and 7.

TABLE IV—Variation of the Means and Standard Deviations of the Shell-Weight per Cubic Centimeter. Volume of Nut for Samples of Three Varieties of Pecan Nuts Grown in Different Localities in 1936

Variety	Crop Year	Locality	No. Nuts in Sample	Mean Shell-Weight Per CC Volume of Nut	Standard Deviation
Burkett	1936	Brownwood, Tex.	49	0.3883	0.0186
Burkett	1936	Stephenville, Tex.	38	0.3477	0.0124
Burkett	1936	Austin, Tex.	40	0.3160	0.0212
Sovereign	1936	Stephenville, Tex.	48	0.3608	0.0153
Sovereign	1936	Rogers, Tex.	40	0.3387	0.0094
Stuart	1936	Austin, Tex.	39	0.4099	0.0139
Stuart	1936	Houston, Tex.	40	0.3699	0.0230

From the data in Table IV it is observed that the standard deviation for most of the samples is sufficiently large to indicate considerable variation in ratios of shell-weight to volume for individual nuts in a sample, but the most interesting revelation is the great variation in the means of these ratios for samples of nuts of the same variety grown in different localities. In every case this ratio was greater for nuts of

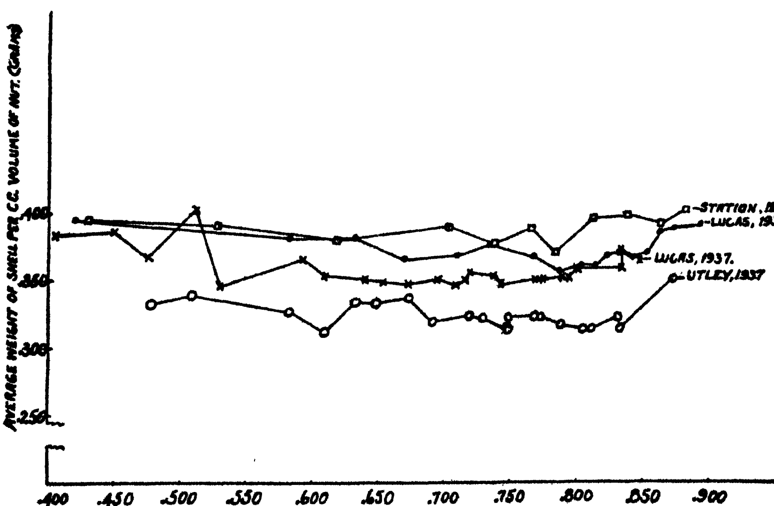


FIG. 5. The average shell-weight per cubic centimeter of nut-volume for pecan nuts in different specific gravity ranges (Burkett variety, 1936 and 1937). Each point on a curve represents averages for 4 to 20 nuts.

the same variety when they were grown under relatively low humidity conditions.

The same phenomena are illustrated in Figs. 5, 6, and 7. For instance, as shown in Fig. 5 the shell-weight per volume of nut was considerably higher for Burkett nuts of the 1937 crop from the Lucas orchard near Brownwood than for those of the same variety grown

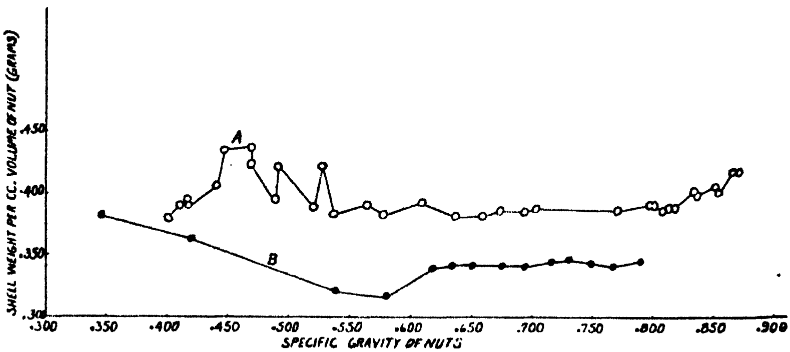


FIG. 6. The average shell-weight per cubic centimeter of nut-volume for pecan nuts of different specific gravity ranges (Success variety, 1937). A, nuts grown at Brownwood, Texas. B, nuts grown at Albany, Georgia. Each point on the curves represents the data from 4 to 26 nuts.

at Utley, Texas, which is some 150 miles southeast of Brownwood. It is also noted that for the most part the shell-weight/volume ratio was lower for the 1937 crop of Burkett nuts from the Lucas orchard than it was for those of the 1936 crop from the same orchard. The nuts in both years came from the same trees. Thus is shown the variability of the shell-weight per unit volume for nuts of a single variety in different seasons and in different localities.

The data in Fig. 6 show that the shell-weight per unit volume of nut for the Success variety grown in the Lucas orchard at Brownwood was much higher on the whole than that for Success nuts grown at Albany, Georgia, the same year. There was considerable variation in the shell-weight/volume ratio within the samples of nuts from each orchard but on the whole the variations were greater for nuts of extremely low and extremely high specific gravity ranges.

The shell-weight/volume ratio for nuts of the Schley variety was generally lower than that for the Burkett and Success nuts of equal specific gravity grown in the same locality (see Fig. 7). Schley nuts grown in the Lucas orchard at Brownwood, Texas, had a much higher shell-weight/volume ratio than did those grown at Albany, Georgia. As was true for the other varieties studied the shell-weight per unit of volume tended to increase for the nuts of very high specific gravity, whereas in nuts of other specific gravity ranges it was about equal although there were fluctuations. There were very few nuts in the extremely high specific gravity ranges in any of the varieties, and the increased shell-weight/volume ratio is probably not significant. The data presented show that the shell-weight per cubic centimeter of nut

volume is not constant for a random sample of a crop, or of a variety, and that it varies considerably for nuts of the same variety from different orchards in the same locality in the same year. It also varies appreciably for nuts of a single variety grown on the same trees in different years, and more widely in nuts grown in widely separated areas in the same or in different years. In all varieties tested, the shell-weight per unit volume was higher for nuts grown in the semi-arid climate at Brownwood than for those of the same variety grown in the humid climates of Albany, Georgia, and Shreveport, Louisiana, or

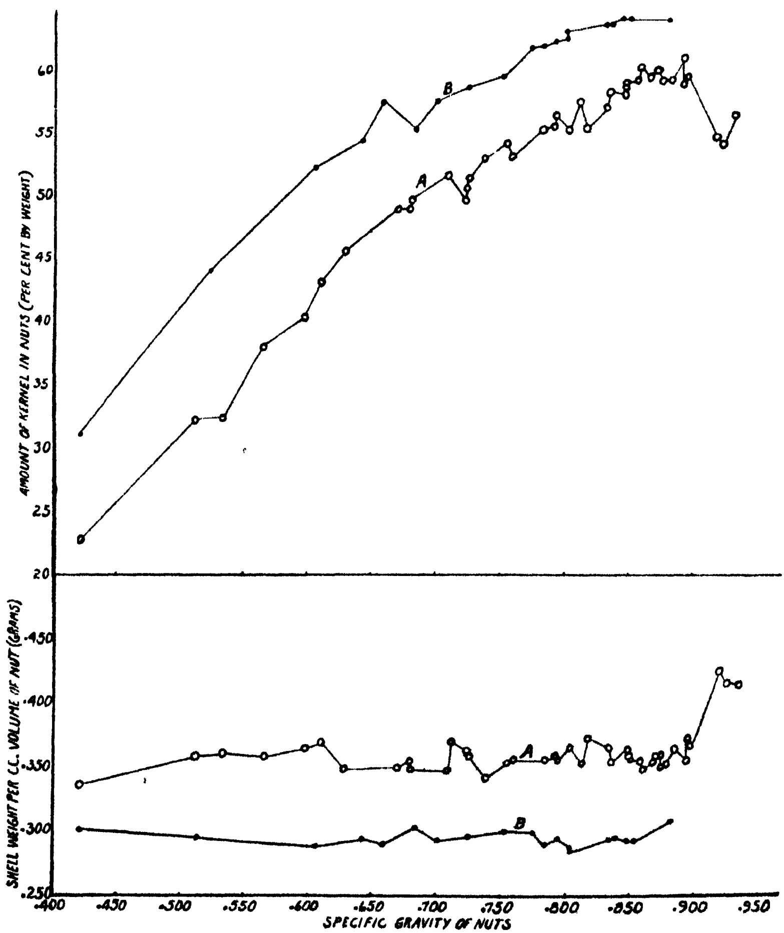


FIG. 7. Lower Chart. The average shell-weight per cubic centimeter of nut-volume for pecan nuts of different specific gravity ranges (Schley variety, 1937). A, nuts grown at Brownwood, Texas. B, nuts grown at Albany, Georgia. Each point on the curves represents the data from 4 to 26 nuts. Upper Chart. Percentages of kernel by weight for the nuts of the same two crops.

even for those grown under the slightly more humid climates of Utley, Stephenville, Rogers, and Austin, Texas. This means that nuts of a variety grown at any of the four places last named would contain a higher percentage of kernel than those of the same specific gravity grown at Brownwood. This fact is illustrated in Fig. 7 for the Schley variety, and was also true of the Burkett and Success varieties.

The specific gravity of shells of the same variety grown in the different localities was about the same. Thus, nuts of a variety grown at Brownwood, Texas, must have considerably thicker shells than nuts of the same variety grown at Albany, Georgia, or in the more eastern sections of Texas. These variations make shell-weight per unit volume of nut an unsafe criterion for use in accurate calculations of percentage of kernel from specific gravity determinations, unless it is determined for nuts of each variety from each orchard or locality each season. If the shell-weight per unit volume were determined on reasonably large random samples of nuts of each variety grown in a given locality each season, the mean would be a fairly accurate factor for use in calculating the percentage of kernel from specific gravity determinations, provided the nuts were uniformly cured.

Discussion and Conclusions

Since the specific gravity varied greatly with varying moisture content of pecan nuts it could not be used as a criterion in evaluation of the filling of nuts even of the same variety unless the nuts were uniformly cured. Variations in moisture content of nuts also cause variations in the ratios expressing shell-weight per unit volume of nut and in those for kernel-weight per unit of volume.

The shell-weight per unit volume of nut varied so widely in nuts of different varieties and in those of the same variety grown in different regions or in different seasons, that this factor makes it unsafe to use specific gravity as a criterion in comparing the kernel development of nuts. The kernel-weight per unit of volume of whole nut would be a better criterion of the filling of nuts of a variety since it would indicate the relative amounts of kernel, but it could not be used for comparison of the filling of nuts of different varieties because of the variations in their normal percentages of kernel.

From the data presented it is evident that specific gravity alone is not reliable as a criterion for comparing the filling of pecan nuts of different varieties or of those of a single variety grown in different localities or in different seasons. It is true that a range of specific gravity can be established for nuts of any variety within which the cured nuts will be of good quality regardless of where they are grown, but nuts of the same specific gravity do not necessarily contain the same amount or quality of kernel. Romberg *et al* (3) stated that specific gravity was a better index of kernel development in pecan nuts than was percentage of kernel, but further studies have invalidated that statement. Percentage of kernel varies much less with changes in moisture content of uncured nuts than does specific gravity. Neither specific gravity nor percentage of kernel accurately indicates quality

of the kernel in a nut, but percentage of kernel does indicate the proportion of the nut that is edible.

For commercial grading of cured pecan nuts specific gravity could be correlated with a standard for each variety, and when used in this manner it probably would result in more uniform grading than is accomplished by present methods. This is indicated to some degree by the work of Sitton (2) and of Dodge (5).

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Self-Incompatibility in Apricots[1]

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Self-incompatibility is of fairly common occurrence in the genus Prunus. There are, however, no reports available of its occurrence in the apricot, *Prunus Armeniaca*.

Most commercial apricot varieties are known to be self-fertile (1) and are frequently planted in large blocks of a single variety. Several newer varieties which are grown on a commercial scale in Washington have not been productive in some orchards. During the past two seasons pollination studies were conducted on these and other varieties in conjunction with apricot breeding work.

Materials and Methods

The experimental work was done on 7- to 10-year-old trees in good vigor at the Irrigation Experiment Station, Prosser, located in the lower Yakima Valley. The varieties Blenheim, Perfection, Riland, Royal, Tilton, and Wenatchee Moorpark were used.

Blossoms which were used for pollination were emasculated when in the "balloon" stage before anther dehiscence or parting of the petals occurred. Blossoms which were either more advanced or had not yet reached the "balloon" stage were pinched off, resulting in a certain amount of blossom thinning. The blossoms which were emasculated would normally have opened in 1 to 3 days, depending on prevailing air temperature, as indicated by similarly thinned but unemasculated check branches. The time for pollen application was usually gaged by the opening of the blossoms on similarly thinned check branches. Blossoms which were not emasculated were thinned the same as were those which were emasculated.

Pollen was collected by picking blossoms in the "balloon" stage and rubbing them across fine mesh wire screen, so the anthers dropped into a mason jar. The pollen was then dried rapidly at room temperature and stored in a cool dry place. A single pollen collection for each pollen parent was used for all pollinations each year. Small samples carried in glass vials were in turn taken from the stock collection and these were discarded after each use. A very reliable, convenient, and economical application of pollen was obtained by using an alcohol sterilized red rubber eraser on a lead pencil for transferring the pollen to the stigma.

In 1946 most blossoms were bagged from time of emasculation until about 1 month after pollination for all crosses. Both white parchment paper pollination bags and fine mesh cheesecloth bags were used, but bagging necessitated the use of a greater number of small branches.

Results from a large number of blossoms that were emasculated, but not hand pollinated or bagged, indicated that practically no fruit would

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set under these conditions. Likewise, blossoms which were emasculated and bagged, but not hand pollinated set no fruit. Consequently all crosses in 1947 were made on blossoms which were emasculated but not bagged, except in the case of self pollinations. The latter were bagged but not emasculated. In 1946 some blossoms on each variety were thinned and bagged but given no further pollination as a check on self pollination in the absence of insects.

The per cent set is based on counts made 6 to 8 weeks after pollination in both years. At this time the drop from incomplete pollination was apparently over. This count is believed to be more reliable than the final count made when the fruit was ripe because, in spite of usual precautions, some fruit was inevitably knocked off in thinning, harvesting, and other orchard operations before the final counts were made.

Experimental Results

The varieties Blenheim, Royal, Tilton, and Wenatchee Moorpark had satisfactory to very good sets when bagged but not emasculated even without supplemental hand pollination. However, the set on Blenheim and Tilton was improved materially by supplemental hand pollination. The results are summarized in Table I. Detjen (2) has reported comparable results from simple bagging of peach blossoms.

TABLE I—Percentage of Self-Pollinated Blossoms Which Set Fruit on Bagged Branches With and Without Artificial Pollination in 1946

Variety	No. Blossoms Bagged; Not Hand Pollinated	Per Cent Set	No. Blossoms Hand Pollinated	Per Cent Set
Perfection	229	0	51	2.0
Riland	172	0	143	0
Wenatchee Moorpark	123	16.3	151	22.5
Royal	141	34.0	178	27.6
Blenheim	175	5.1	115	18.3
Tilton	184	9.2	119	22.7

Riland did not set fruit with either treatment while Perfection had a set of 2 per cent from supplemental hand pollination, but no set from simple bagging.

The set which occurred from simple bagging apparently resulted from the stigma of a flower being brushed by anthers from the same flower. Under normal blossoming conditions the filaments are of such length that the anthers are frequently brushed against the stigma by the wind at a time when the stigma is receptive.

The per cent fruit set resulting from self- and cross-pollinations for 1946 and 1947 is presented in Table II. In 1946 crosses in all combinations with the six varieties were made except that the combinations Royal x Riland, Royal x Blenheim, Royal x Tilton, and Blenheim x Royal were omitted. In 1947 an unusually early and warm blossoming period made it necessary to reduce the number of combinations made.

The data in Table II indicate that Perfection gave a negligible set

in 1946 and no set in 1947, when self-pollinated. However, when Perfection was pollinated by any of the other varieties, or when any of the other varieties were pollinated by Perfection, the set was satisfactory in both years.

Riland, when self-pollinated, gave no set in 1946. The set of 1.8 per cent from self-pollination in 1947 is of interest in that the blossoms were pollinated twice. They were bagged on March 17 and were open and ready for pollination on March 18 when they were pollinated the first time, but the pollination was duplicated on March 19. In 1946 Riland x Blenheim also gave a very low per cent set, but it may be seen that Blenheim pollen gave relatively poor sets on most varieties in 1946 while in 1947 it gave very good sets. Apparently the Blenheim pollen used in 1946 was not of good quality for some unknown reason. Riland, when used as either a pistillate or pollen parent showed no incompatibility with the other varieties used in 1946 or in 1947.

TABLE II—SUMMARY OF FRUIT SET FROM SELF- AND CROSS-POLLINATIONS

Pistillate Parent	Staminate Parent	1946		1947	
		No. Flowers	Per Cent Set	No. Flowers	Per Cent Set
Blenheim	Selfed	115	18.3	—	—
	Perfection	174	13.8	119	42.0
	Riland	310	26.1	248	47.6
	Tilton	259	14.7	203	44.3
	Wenatchee Moorpark	242	11.6	—	—
Perfection	Selfed	51	2.0	262	0
	Blenheim	228	3.1	965	32.3
	Riland	121	25.6	273	60.8
	Royal	229	15.3	—	—
	Tilton	340	7.1	565	51.0
	Wenatchee Moorpark	223	10.3	—	—
Riland	Selfed	143	0	272	1.8
	Blenheim	227	0.4	263	40.3
	Perfection	172	22.7	273	10.6
	Royal	289	14.5	—	—
	Tilton	223	4.0	252	25.0
	Wenatchee Moorpark	186	4.8	—	—
Royal	Selfed	178	37.6	—	—
	Perfection	312	31.1	—	—
	Wenatchee Moorpark	79	30.4	—	—
Tilton	Selfed	119	22.7	—	—
	Blenheim	111	17.0	137	44.5
	Perfection	189	28.0	161	38.5
	Riland	266	24.1	169	26.6
	Royal	178	10.7	—	—
	Wenatchee Moorpark	48	0	—	—
Wenatchee Moorpark	Selfed	151	22.5	—	—
	Blenheim	176	7.4	—	—
	Perfection	180	40.0	—	—
	Riland	167	4.8	—	—
	Royal	197	26.4	—	—
	Tilton	206	11.2	—	—

Tilton x Wenatchee Moorpark did not result in a set in 1946 and the cross was not repeated in 1947. It is believed that this failure may be due to factors other than cross-incompatibility.

The varieties Blenheim, Royal, Tilton, and Wenatchee Moorpark gave satisfactory sets from self- or cross-pollinations except as indicated above.

The data in Table II indicate that the per cent set was generally

higher in 1947 than in 1946. A possible explanation is that the trees had an exceptionally heavy bloom in 1946 when a large number of small fruiting branches were used for pollination while in 1947 the bloom was relatively light and large branches were used for pollination. The result was that the blossoms used for pollination in 1947 had less competition for fruit set from nearby open pollinated blossoms than did those used in 1946.

Microscopic inspection of pollen grains of all six varieties revealed that they were essentially all normal and sound in appearance. Limited germination tests with Riland and Perfection resulted in excellent germination percentages.

The failure of Riland and Perfection to set fruit when self-pollinated appears to be due to self-incompatibility. A per cent fruit set of the order of magnitude obtained with Perfection in 1946 and Riland in 1947 is not unusual when dealing with self-incompatible fruit varieties. Such light sets are commercially worthless. Both Riland and Perfection are cross-compatible with each other, just as they are with all other varieties used in this study. Although Tilton is genetically satisfactory as a pollinizer for these two varieties, it normally blooms somewhat late and cannot be depended on for a satisfactory overlapping of bloom in Central Washington.

Summary

Data are presented to show that a satisfactory fruit set with self-compatible varieties can be obtained without insect pollination. Under such conditions individual blossoms are self-pollinated as a result of the wind brushing the anthers against the stigma.

The varieties Perfection and Riland are shown to be self-incompatible while the varieties Blenheim, Royal, Tilton and Wenatchee Moorpark are self-fertile. All six varieties are cross-fertile. The pollen of Perfection and Riland is functional and normal in appearance.

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Influence of Temperature Following Bloom on Fruit Development Period of Elberta Peach

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THERE is need for a reliable means of estimating early the time of ripening of the peach crop. Interest is expressed each spring by peach growers and others in the probable harvest date, particularly in south central Georgia where the earliest peach shipments begin each season. Growers can use this information to plan for harvest and packing house labor; and buyers, shippers, and packing house suppliers, to plan their operations.

The time of full bloom marks a definite stage in the development of fruit and has been used as an index of future fruit development. The interval between full bloom and fruit maturity is specific for each variety, with variations from year to year due to various factors. Several workers (4, 5, 6) have suggested that in the case of apples, peaches, pears, and cherries, practical use of this interval may be made in determining harvest dates. With blueberries (1) the length of the development period is too variable to be of use in estimating maturity. Baker and Brooks (2) have adopted a system of heat units to be used as a correction factor in estimating time of maturity of apricot and prune fruits. Blake (3) stated that April and May temperatures chiefly affect the length of the development period of peach fruits at New Brunswick.

It was noted that at Fort Valley, Georgia, the elapsed time from full bloom to first commercial picking of Elberta peaches has ranged in the past 10 years between 104 days and 124 days, with a mean of 113 days. An estimate of maturity date based on date of full bloom and the average 113-day fruit development period could be off as much as 11 days. The date of full bloom has varied in the same years from as early as March 1 to as late as April 4. An early or late time of bloom has not necessarily resulted in a respective early or late time of maturity, though an early bloom tends to result in a longer development period and a late bloom in a shorter development period.

To correct for some of the variability in the length of the fruit development period, an attempt was made to correlate temperatures following full bloom with fruit development. Temperatures recorded by the cooperative station of the United States Weather Bureau at Fort Valley were used. For fruit maturity dates, the date of first picking in a large commercial Elberta orchard was used in all years except 1938. The dates of full bloom for the 10-year period are shown in Table I, together with the observed number of days from full bloom to first picking and the estimated number of days on the basis of mean maximum temperatures for the 50-day period following bloom. The mean maximum temperatures for certain other periods following bloom are also given. It can readily be seen that, as shown by Blake (3), high temperatures following bloom have resulted in a shorter interval between bloom and fruit maturity.

TABLE I—LENGTH OF FRUIT DEVELOPMENT PERIOD OF ELBERTA PEACH AND MEAN MAXIMUM TEMPERATURES FOLLOWING BLOOM

Date of Full Bloom	No. Days From Bloom to First Picking		Mean Maximum Temperature for the Indicated Period After Bloom				
	Obs.	Est.*	30 Days (Degrees F)	40 Days (Degrees F)	50 Days (Degrees F)	60 Days (Degrees F)	70 Days (Degrees F)
Apr 4, 1947	104	105	78.7	79.1	80.6	81.2	82.5
Apr 4, 1941	105	102	79.3	79.7	82.4	84.2	85.2
Mar 20, 1943	109	113	72.3	73.4	76.1	77.4	78.3
Mar 26, 1942	111	108	74.7	78.2	79.1	79.8	80.5
Mar 2, 1945	112	110	77.3	76.8	77.8	77.9	77.4
Mar 15, 1939	114	116	73.4	74.0	74.7	75.7	76.2
Mar 5, 1946	114	114	74.0	75.0	75.7	76.2	76.8
Mar 25, 1940	115	117	72.0	71.8	74.4	76.7	77.9
Mar 1, 1938	118	118	74.6	73.3	73.7	74.5	75.7
Mar 5, 1944	124	123	69.3	70.0	71.0	71.8	72.9
Coefficient of correlation, temperature with observed interval			−0.80	−0.85	−0.93	−0.93	−0.91

*Calculated by regression, based on mean temperature for the 50-day interval.

The average maximum temperature for the first 30 days following bloom shows a —.80 correlation with the length of the fruit development period (Table I). The correlation increases through the 40-day period to a value of —.93 for the 50-day period. Increasing the period to 60 and 70 days does not show any further increase in correlation. Apparently most of the effect of the maximum temperatures on the rate of fruit development occurred during the first 50 days following bloom.

Correlations have been worked out also for the relation between average minimum temperatures following bloom and the length of the fruit development period. The coefficients of correlation for the minimum temperatures for the 30-, 40-, and 50-day periods are —.75, —.84, and —.87, respectively, somewhat less than those for the maximum temperatures. The higher coefficients of correlation found for the 60- and 70-day periods, —.94 and —.94, may be due to an influence of low minimum temperatures late in the season. In no instance was the minimum temperature correlation significantly greater than the —.93 value for correlation with maximum temperatures for the 50-day period following bloom. Since the mean maximum temperature for the 50-day period is the earliest of the more reliable temperature averages to become available, the figure for this period has been used to calculate, by regression, the length of the fruit development period and the consequent date of ripening (Table I). A measure of its reliability is shown in Fig. 1, which illustrates graphically the relation between average maximum temperatures for 50 days following bloom and the length of the fruit development period in each of the past 10 years, with the straight line of closest fit.

The deviation of the calculated length of the fruit development period from the observed length was 1.8 days on the average, and was 2 days or less in 7 of the 10 years (Table I). The greatest difference between the expected and observed dates of ripening in any year was 4 days. The estimates were much closer when the maximum temperatures early in the season were below average and the fruit required longer than the 113-day average to develop. Greatest deviation oc-

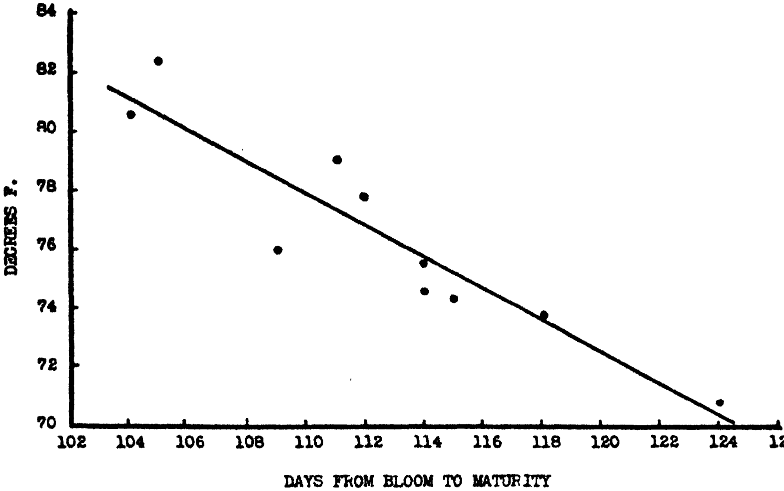

FIG. 1. Relation between mean maximum temperature for 50 days following full bloom and length of Elberta fruit development period, 1938 to 1947, with straight line of closest fit.

curred when temperatures averaged above normal. An increase of 1 degree in the average maximum temperature for the 50 days following bloom shortened the length of the fruit development period 1.86 days.

The other principal commercial varieties of peaches were influenced similarly by early season temperatures, though not always to the same degree. The same maximum temperature means were not applicable to all varieties because of the difference in time of full bloom among varieties. Mayflower variety, having a high chilling requirement to break the rest period of its buds, blossomed 10 days later than Elberta on the average. Contrary to observations (6) at Geneva, New York, early maturing varieties showed less variation in the length of their fruit development period than did Elberta. Mayflower, for example, ranged between 49 days and 56 days during the 10-year period, with an average development period of 53 days. The average fruit development periods of Early Hiley and of Hiley were 92 and 99 days, respectively, with respective differences of 16 and 17 days between extremes. In comparison, the longest development period of Elberta was 20 days greater than the shortest period.

At Fort Valley the average date of full bloom of the Elberta variety during the past 10 years was March 17. The mean temperature of March 17 at Fort Valley was 57 degrees F. This relatively high temperature at full bloom, and subsequent higher temperatures, were no doubt partially responsible for the relatively short interval (113 days) between bloom and fruit maturity in comparison with Elberta grown in other sections of the country. In New Jersey (3) and at Geneva (6) the elapsed interval for Elberta peaches was reported to be 128 days. Peach trees at Fort Valley are delayed in blossoming because the

rest period of their buds is not broken until relatively late in the season, and therefore, the buds are not greatly influenced by relatively high temperatures occurring during mid-winter. Often Elberta trees at Fort Valley bloom only 2 days earlier than in areas 250 miles to the north, but relatively warm weather following bloom advances Fort Valley peaches to a much earlier harvest.

Many other factors, such as size of crop, age of tree, growth of tree, and nitrogen supply, affect the length of the fruit development period aside from temperature. However, by correcting the average length of the fruit development period for early season temperature effects, more than half of the variability between the expected and the observed date of ripening is eliminated. It is appreciated that 10 years' observation is barely long enough for a basis of calculation, and further observations should tend to increase reliability of estimates.

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Foliar Diagnosis: Comparison of Diseased and Healthy Leaves from the Same Tree in a Peach Orchard Infected with Bacterium Pruni[1]

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OWING to the phenomenon of migration of the mineral elements from leaves undergoing the normal processes of senescence, only metabolically active leaves are used in foliar diagnosis studies. If a diseased leaf behaves similarly to one undergoing normal senescence the conclusions with respect to the mineral status of a tree from the data of the composition of affected leaves may not be valid. Investigators faced with the problem of using diseased or healthy leaves usually have selected only healthy leaves, and where both diseased and healthy leaves have been taken, badly diseased leaves have been avoided on *a priori* considerations (1, 3).

Two conditions may exist which may make it either necessary or desirable to select necrotic leaves. The first condition would be presented if a weak or very young tree should not provide a sufficient quantity of healthy leaves for analysis when a series of successive samplings is required throughout the growing season; the second condition would exist if susceptibility to attack by a particular organism, in this case *Bacterium pruni*, results from a deficiency of one or more elements. In the latter event the question arises whether the composition of diseased leaves would show a greater difference with respect to the critical element from that of the normal leaves from a vigorous tree, and thus provide a more sensitive index in diagnosis. Among experiments on a disease known to be the result of a deficiency of an element, the most exhaustive work has been carried out by Goodall (2) on chlorosis (scorch) resulting from a deficiency of potassium (or of magnesium) in apple trees. He found that the concentrations of potassium, calcium, magnesium, sodium, iron, and manganese in slightly scorched leaves did not differ significantly from those of healthy leaves from the same tree, except that the content of magnesium was consistently lower in scorched leaves of trees deficient in magnesium; also in severely scorced leaves the manganese content was lower than that in healthy leaves from the same tree. Goodall concludes that slight scorch has no disadvantage and may even facilitate the diagnosis of magnesium deficiency.

We are not aware of any work on the composition of necrotic and healthy leaves from the same plant, when necrosis is caused by a pathogenic organism and the cause of the susceptibility is unknown.

EXPERIMENTAL

The data in Table I are from two susceptible varieties, Summercrest and Sunhigh, of peach trees in a commercial orchard in York County, Pennsylvania, in which infection by *Bacterium pruni* was

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first observed in 1944. The affected and healthy leaves were sampled on August 28, 1946, from the middle of the terminal growth. Table I gives the percentage of nitrogen, phosphorus, potassium, calcium, magnesium, sodium, manganese, iron, boron, and sulfur in the dry matter for both diseased and healthy leaves from the same tree. Molybdenum also was determined (range 0.3 microgram per gram to 0.15 microgram per gram) and appeared to have little significance. The order in which the trees are placed follows the increase in the degree of infection, the Sunhigh trees being more susceptible than the Summercrest, but of varying degrees of infection.

Discussion of Results

In all cases the content of nitrogen, phosphorus, and potassium is lower in the diseased than in the healthy leaves from the same tree, and with the possible exception of the nitrogen content of F–10 and of the potassium content of K–7 the differences are much greater than the analytical error. The trends in the differences of the nitrogen, phosphorus, and potassium contents of diseased and healthy leaves from the same tree are related to the degree of infection, although in the case of potassium the varieties would have to be considered separately for this statement to hold.

In the tree F–10 showing the least infection, the differences for nitrogen, phosphorus, and potassium are 2.9, 4.7, and 7.1 per cent respectively, of the values for the respective elements in the healthy leaves and for the most severely infected tree U–7 they are much higher, namely 11.2, 18.2, and 20.9 per cent respectively.

The differences in the calcium contents of healthy and diseased leaves from the same tree follow no definite trend with the increase in the degree of susceptibility; but in the very severely diseased tree U–7, calcium is 13.7 per cent higher in the diseased leaves than in the healthy leaves and, therefore, behaves as in a more mature leaf than the morphologically homologous healthy leaves. The trend of the differences for magnesium are somewhat similar to those of calcium. The metabolism of a diseased leaf, therefore, with respect to nitrogen, phosphorus, potassium, calcium, and magnesium is similar to that of one undergoing the normal processes of senescence.

Sodium, manganese, and boron also are always lower in the diseased than in the healthy leaves from the same tree. In the case of sodium and manganese, however, the differences are not significant, being within the limits of analytical error. The error for sodium using the zinc uranyl acetate method is large and the results were erratic. The differences in the boron content are relatively large in the most severely infected trees U–7 and I–7, but lie within the limits of the analytical error for the other trees. The contents of sulfur and iron always are higher in the diseased leaves, and in the case of iron in the very severely diseased tree U–7, reach as much as 18.5 per cent.

Although the differences between healthy and diseased leaves reach relatively high values particularly for nitrogen, phosphorus, potassium, calcium, iron, and boron in the severely infected tree U–7, nevertheless the value for the contents of every element determined lie within

TABLE I—COMPOSITION OF NORMAL AND DISEASED LEAVES FROM PEACH TREES ATTACKED BY BACTERIUM PRUNI

No. of Tree	Condition of Leaves	N (Per Cent)	P (Per Cent)	K (Per Cent)	Ca (Per Cent)	Mg (Per Cent)	Na (Per Cent)	S (Per Cent)	Mn Micrograms /Gm	Fe Micrograms /Gm	B Micrograms /Gm	Position With Respect to Fertilizer Treatment	Condition of Tree
Summercrest F10	Normal	3.13	0.213	1.67	2.23	0.437	0.235	0.138	73	182	35.0	Buffer across from tree which received 15 pounds KCl fall 1945	Relatively healthy
	Affected	3.04	0.203	1.56	2.03	0.393	0.203	0.143	69	183	33.0		
Summercrest Q10	Normal	3.10	0.198	1.74	2.00	0.320	0.304	—	71	192	37.5	In no treatment block	Relatively little diseased
	Affected	2.90	0.181	1.56	1.73	0.349	0.260	—	69	200	33.0		
Sunhigh K7	Normal	3.22	0.240	1.91	1.78	0.349	0.257	0.137	77	200	35.5	Buffer tree between trees which received 5 and 10 pounds respectively KCl Aug. 1946	Moderately diseased
	Affected	2.94	0.218	1.89	1.78	0.305	0.224	0.149	69	210	33.5		
Sunhigh I7	Normal	3.10	0.231	2.20	1.74	0.371	0.242	0.147	75	220	35.5	Buffer tree between trees which received nothing and 5 pounds KCl respectively, Aug 1946	Rather severely diseased
	Affected	2.84	0.211	2.09	1.75	0.378	0.208	0.152	67	237	26.0		
Sunhigh U7	Normal	3.31	0.252	2.39	1.74	0.349	0.231	0.152	55	200	35.5	In no treatment block	Very severely diseased
	Affected	2.94	0.206	1.89	1.98	0.356	0.220	0.165	51	237	30.0		

the recognized critical limits for the period of sampling considered. The data for the composition of the most severely infected leaves, accordingly, would not lead to any false diagnosis with respect to deficiency or excess of an element. But even when no actual deficiency of an element occurs, growth and development are influenced also by the interrelationships among the nutrients. Considerable progress has been made in our knowledge of the interactions among the primary elements nitrogen, phosphorus, and potassium as indices of the effect of the addition of these elements (6). If the relationship among the other nutrient elements is suspected as a factor in the problem to be investigated, it would seem that the most profitable line of attack is the examination of the way in which variation in the interactions of the primary element affects the other elements. An example of this approach is that of the relationships among nitrogen, phosphorus, potassium, and boron (4); and this approach will be considered further in the following paper (5).

Summary

Samples of median leaves from terminal growths of two varieties of peach, Sunhigh and Summercrest, which exhibited symptoms of varying severity of attack by *Bacterium pruni*, were taken from an orchard in York County, Pennsylvania, on August 28, 1946, and healthy and diseased leaves from each tree were analyzed for their content of nitrogen, phosphorus, potassium, calcium, magnesium, sodium, manganese, iron, boron, and sulfur. The differences between healthy and diseased leaves indicated that the latter were further advanced toward senescence than were the former; this difference with respect to nitrogen content was progressive with the degree of infection, the greater the percentage of infection, the greater the reduction in nitrogen in the diseased leaves, in comparison with the healthy ones, an indication that the farther advanced in senescence was the metabolism of the diseased leaves in relation to that of the healthy ones on the same tree. These circumstances suggest that, in general, healthy leaves should be used as a basis of comparison in attempting to ascertain the nutritional conditions associated with resistance or susceptibility of plants to infection by a disease.

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Foliar Diagnosis: Nutritional Factors in Relation to Bacterial Leaf Spot of Peach[1]

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INFECTION by *Bacterium pruni* was observed in a commercial orchard in York County, Pennsylvania, in which an experiment on potash fertilization was begun in 1946. The data on the composition of diseased and normal leaves from the same tree are presented in a preceding paper (10). The incidence of attack was more severe in some varieties than in others, being severe in Sunhigh and moderate in Summercrest. Other varieties not considered in this paper were affected to a lesser degree.

Peach trees appear to be easily injured by lead arsenate sprays and there is evidence that the use of this spray prior to 1946 may have been a factor in the invasion of this organism. This deduction is made from the results of tests for arsenic on branches, twigs, and petioles which showed injury. The necrotic areas of the cambium, phloem, and xylem tissues gave strong tests for arsenic.

The control or reduction of infection by *Bacterium pruni* in peach orchards by the use of non-arsenical sprays has been reported by a number of investigators. Poole (3) found that cuprocide (red copper oxide), copper phosphate and also coposil (ammonium copper silicate) gave more satisfactory reduction than any of the other chemicals usually used. Roberts and Pierce (5) found that a spray containing a mixture of zinc sulfate, hydrated lime, and casein-lime checked infection without noticeable injury and gave better control than sulfur sprays or dusts Anderson (1) reported that a spray of sodium silicofluoride (1–200 solution) completely controlled bacterial leaf spot without serious injury to the tissues of the peach trees. In the Pennsylvania orchard under examination, all sprays used failed to give any control of the disease.

The physiological mechanism of resistance to attack by a pathogenic organism is not understood. It is well known that species differ in their resistance to attack by any specific organism and that varietal differences in susceptibility also occur. In some diseases resistance appears to result from the inability of the organism concerned to find the proper nutritive conditions in the host plant. Such an hypothesis is applicable to the results obtained by Poole (4) in which 1 pound of $NaNO_3$ was applied every 2 weeks to 12-year-old Elberta peach trees attacked by *Bacterium pruni*. This treatment resulted in but slight infection compared with that in the controls and resulted in much higher contents of potassium, calcium, magnesium, and iron in the trees. Unfortunately, the tissues examined are not given, nor are the contents of nitrogen and phosphorus of treated trees compared with the controls. As already pointed out in the preceding paper (10) insofar as the recognized critical limits can be used as an index of deficiency

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or excess of an element, the values for all the nutrients determined in our experiments in the median leaves of the terminal growths at the particular period of sampling are within the normal ranges. This quantitative evaluation, however, needs to be supplemented with the qualitative evaluation of their interactions.

Experimental

The orchard is situated on a hillside in York County, Pennsylvania, on a Chester silty soil very low in organic matter. There are only two developed soil horizons; the surface soil has disappeared leaving only the sub-surface and sub-soil. Rock ledges are encountered as little as 5 inches below the surface.

Many varieties of peaches are grown in this orchard, among which are J. H. Hale, White Hale, Triogem, Afterglow, Halberta Giant, Golden Globe, Elberta, Goldeneast, Raritan Rose and the two varieties Summercrest and Sunhigh used in this exploratory study. Infection by *Bacterium pruni* was observed first in 1944. The trees selected for this study were buffer trees in a potash experimental block. All trees, however, had received a basic dressing of 600 pounds of 10–10–10 fertilizer per acre in the Spring of 1946, and previously had received from 200 to 300 pounds of 10–6–4 to the acre, or approximately this analysis, each year. The analytical data show no evidence of cross feeding.

Table I gives the composition with respect to nitrogen and nine of the ash constituents of *healthy* leaves from the middle of the terminal growth sampled on August 28, 1946, together with information on the condition of the trees and their position in the fertilizer block. In Fig. 1 are given the intensities of nutrition with respect to the fertilizer entities nitrogen, phosphoric acid, and potash and also the equilibrium between them as indicated by the composition of the *NPK-units* (7) of *healthy* leaves, and Fig. 2 the data for *diseased* leaves. Fig. 3 shows the position of the loci of the *CaMgK-units*. Each locus is represented by a point in the trilinear co-ordinate diagram.

Discusssion

The relationships that have been found to exist among the major elements and particularly the primary fertilizer elements to growth and development in all our investigations on foliar diagnosis (8) testify to the importance of a consideration of the nutrient element balance among the fertilizer "entities" and also of the intensity of nutrition in determining the growth responses to fertilizers. These concepts have received further attention from Shear *et al* (6), who consider it necessary to extend them to include all the nutrient elements. In support of this view, reference is made by them to numerous experiments in which a deficiency of some element is produced by an unbalanced condition with respect to any one of a number of elements both major and minor.

It is a relatively simple matter to determine the interactions among the three primary component systems in fertilizer experiments when each of the other factors remains equal or approximately so; if not,

TABLE I—COMPOSITION WITH RESPECT TO NITROGEN AND ASH CONSTITUENTS OF HEALTHY LEAVES FROM THE MIDDLE OF TERMINAL GROWTHS OF TWO VARIETIES OF PEACH TREE WITH DIFFERENT DEGREES OF INFECTION TO BACTERIUM PRUNI

Variety and Tree Number	N (Per Cent)	P_2O_5 (Per Cent)	K_2O (Per Cent)	CaO (Per Cent)	MgO (Per Cent)	Na_2O (Per Cent)	SO_4 (Per Cent)	MnO (Mgm/Gm)	Fe_2O_3 (Mgm/Gm)	B_2O_3 (Mgm/Gm)	Ratio K_2O/N As Percentage Values	Ratio K_2O/N In Composition of NPK-unit	Ratio $\frac{Fe_2O_3}{MnO}$	Ratio $\frac{Fe}{Mn}$	Intensity ($N+P_2O_5+K_2O$) (Per Cent)	Composition of *NPK*-unit	Position of Tree in Fertilizer Block	Condition of Tree
Summercrest P 10	3.13	0.488	2.01	3.13	0.724	0.317	0.075	94	260	119	0.642	0.189	2.7	2.5	5.63	77.9:7.2:14.9	Buffer across from tree receiving 15 pounds KCl, Fall 1945	Relatively healthy, about 5 per cent infection
Summercrest Q 10	3.10	0.454	2.10	2.80	0.531	0.410	—	92	274	127	0.677	0.204	2.9	2.7	5.65	77.4:6.8:15.8	In no-treatment block	Relatively little diseased, about 15 per cent infection
Sunhigh K 7	3.22	0.550	2.44	2.49	0.700	0.347	0.070	99	286	121	0.758	0.224	2.9	2.7	6.21	75.3:7.7:17.0	Buffer tree between trees receiving 5 and 10 pounds respectively KCl, Aug. 1946	Moderately diseased, about 30 per cent infection
Sunhigh I 7	3.10	0.527	2.65	2.44	0.615	0.327	0.087	97	314	121	0.855	0.254	3.2	2.9	6.28	73.8:7.4:18.8	Buffer tree between trees receiving 0 and 5 pounds KCl, Aug. 1946	Rather severely diseased, about 60 per cent infection
Sunhigh U 7	3.31	0.577	2.88	2.44	0.579	0.311	0.084	71	286	121	0.870	0.259	4.0	3.6	6.77	73.4:7.6:19.0	In no-treatment block	Very severely diseased, about 80 to 85 per cent infection

they must be discovered and provided for. This is the basis on which all experiments on foliar diagnosis have been planned (7). The report by Shear *et al* (6) is a preliminary report of experiments under way in which tung trees are grown in nutrient solution, and one must await further reports by them as to the manner in which the interrelations among all the elements are to be used as indices in growth and development.

Tree No.	Intensity	Percent Infected
F10	5.63	5
Q10	5.64	15
K7	6.21	30
I7	6.27	50
U7	6.68	85

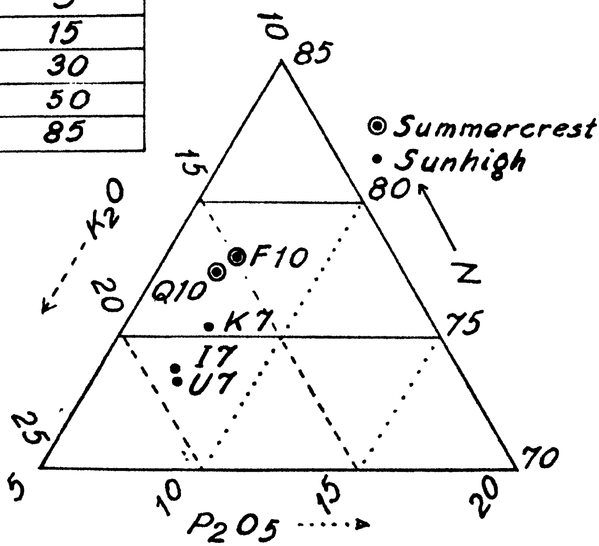

FIG. 1. The intensities of nutrition with respect to nitrogen, phosphoric acid, and potash, and also the equilibrium among them as indicated by the loci of the *NPK-units*. The data are for *healthy* leaves from the middle of the terminal growths taken on August 28, 1946.

It is noted in Fig. 1 that the intensity of nutrition (per cent $N+P_2O_5+K_2O$) increases with an increase in the amount of the infection and that the positions of the loci of the *NPK-units* are likewise correlated with the degree of infection. As nitrogen in the composition of the unit *decreases* the infection *increases* accompanied by increments in the potash, without any regularity in the relationships to phosphoric acid in the *NPK-unit*.

The leaves of the less susceptible Summercrest variety (trees F 10 and Q 10) have considerably higher nitrogen and lower amounts of potash in the composition of the *NPK-unit* than have those of the more susceptible Sunhigh. The relatively healthy tree F 10 has the values: intensity 5.6 and composition of the *NPK-unit* 77.9:7.2:14.9, whereas the most severely infected Sunhigh tree U 7 has intensity 6.8 and composition of the unit 73.4:7.6:19.0. It is of importance

to note that although the percentage of nitrogen (3.31) in the most severely infected of the trees, Sunhigh U 7, is highest of any, the nitrogen in the composition of the *NPK-unit* is the lowest, and although no relationships exist between the percentage of nitrogen in the leaves, there is a correlation between nitrogen in the composition of the *NPK-units* and the amount of the infection, as just pointed out. These facts suggest that the percentage of an element in the leaf, considered alone without any attention being paid to the relationships among the elements, may not always be a reliable index of a deficiency or excess of the element in question.

As stated, the above considerations are based on the composition of *healthy* leaves. The data on the composition of *diseased* leaves with respect to intensity and balance in relation to infection is shown in Fig. 2. Except for the very severely diseased tree U 7, the interrelations among the fertilizer elements are similar to those for the healthy leaves.

Tree No.	Intensity	Percent. Infected
F10	4.97	5
Q10	5.30	15
K7	5.72	30
I7	5.88	50
U7	5.71	85

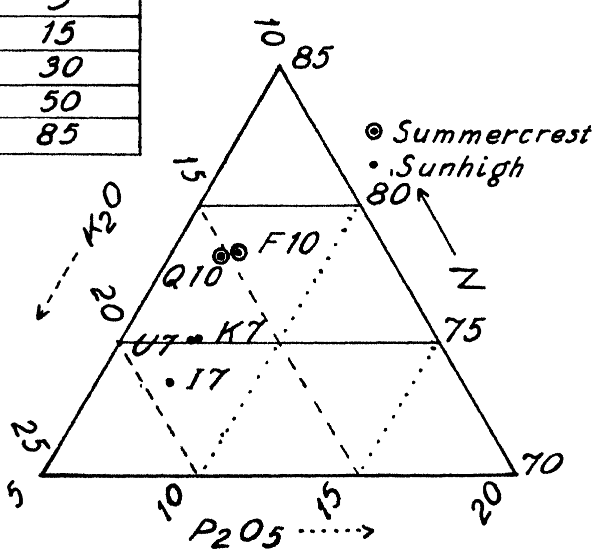

FIG. 2. The intensities of nutrition with respect to nitrogen, phosphoric acid, and potash, and also the equilibrium among them as indicated by the loci of the *NPK-units*. The data are for *diseased* leaves from the middle of the terminal growths taken on August 28, 1946.

Additional information on the relationships among the major elements is given in Fig. 3 in which the loci of the *Ca Mg K-units* for the *healthy* leaves are given. Here the values for potash in the composition of the *Ca Mg K-units* follow the same order in relation to the degree of infection as do the percentage values — as the potash in the compo-

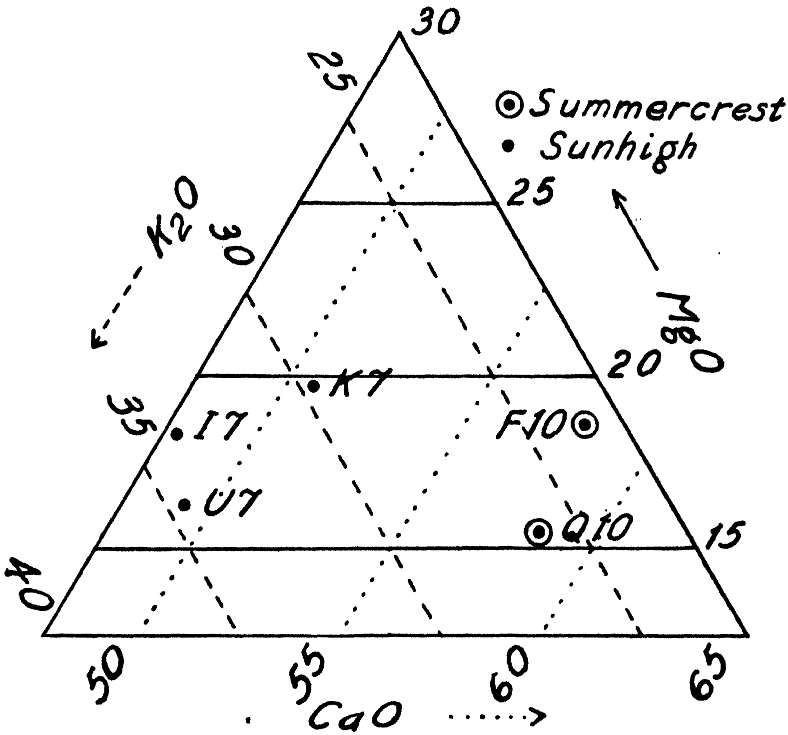

FIG. 3. The equilibrium among calcium (lime), magnesia, and potash as indicated by the *Ca Mg K-units*. The data are for *healthy* leaves from the middle of the terminal growths taken on August 28, 1946.

sition of the unit increases so does the degree of infection. Calcium in the composition of the *Ca Mg K-unit* is much lower in the susceptible Sunhigh trees than in the Summercrest. Magnesium, however, shows no relationship with the amount of infection.

Many workers consider the ratio of potash to nitrogen of significance in relation to susceptibility to attack by pathogenic organisms. Resistance has been found to increase with increase in the ratio of potash to nitrogen (2, 9). The present results are peculiar in this respect in that resistance to attack by *Bacterium pruni* diminishes as the ratio increases.

The only point of agreement of the results from this orchard with those of Poole (4), previously referred to, is that in both cases calcium is lower in diseased trees, and as already pointed out, calcium is much lower in the balance among the bases in the susceptible variety Sunhigh than in the Summercest.

The influence of the iron-manganese balance on the growth and development of plants has received considerable attention of late (11). In nutrient culture solutions the optimum ratio of "active" iron to "active" manganese apparently lies between 1.5 and 2.5, irrespective

of the total amounts of these elements in the tissues; pathological symptoms of manganese deficiency appear when the ratio is greater than 2.5, and of iron deficiency when the ratio is below 1.5. The ratios of total Fe to total Mn in the leaves considered are given in column 15 of Table I. The ratio increases with the degree of infection from 2.5 in F 10 to 3.6 in U 7.

In foliar diagnosis studies it is not practicable to determine the "active" form of the elements, meaning by this the amounts present in the sap and in the soluble condition. Why the soluble form of a constituent should be more important in ascertaining the rôle of an element to growth and development than the amount metabolized is not apparent. If the values of the ratios as given in columns 14 and 15 are indicative of the interactions of these elements in relation to the incidence of disease then the conclusion would be that the badly infected trees I 7 and U 7 are deficient in manganese. It should be pointed out, however, that none of the usual visible symptoms of Mn deficiency were present. But visual symptoms, in general, appear only when the particular deficiency is very great and long after retardation in growth has begun, so that the conditions represented by I 7 and U 7 could be stages of incipient deficiency of manganese. Of significance, perhaps, is the fact that in the diseased leaves the ratios are higher than in the healthy leaves, namely 2.6, 2.9, 3.0, 3.5, and 4.3 proceeding from F 10 to U 7. There is no clear-cut relationship between the Fe/Mn ratio and any of the primary elements, although the idea prevails that this ratio must be influenced by the relationships among them. One notes an inverse relationship between the content of the bases (lime + magnesia) and the ratio of Fe/Mn. As the bases *increase* the Fe/Mn *decreases*.

The situation in the present experiment is evidently complex, and may merely reflect that in this orchard the soil of which is very low in organic matter a relatively low proportion of nitrogen to phosphoric acid and potash in the leaves is not conducive to vigor.

Summary

The nutrition of certain peach trees of the varieties Summercrest and Sunhigh, growing in a commercial orchard in York County, Pennsylvania, and exhibiting since 1944 symptoms of varying severity of infection by *Bacterium pruni*, was examined with respect to the content of 10 elements and the interrelationships among them. The content of potassium increased with the severity of the disease symptoms, whereas the trend for calcium was to decrease. No relationship was found between the content of the remaining nutrients analyzed, major or minor, and the severity of the disease, either among the trees individually or between the two varieties. The ratios of K_2O/N and of Fe/Mn increased regularly with increase in the degree of infection; possibly the latter relation may be simply an inverse association with vigor. An inverse relationship existed between the proportion of nitrogen in the composition of the *NPK-unit* and the degree of infection. It is concluded that infection is related to low vigor resulting from a low proportion of nitrogen in the balance of the primary elements

and is associated with a lack of organic matter in the soil of this orchard.

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Effect of Wax Sprays on the Yield of Cherries, Pears, and Apples[1]

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An economically sound method for increasing the size of cherries and of certain varieties of pears and apples would be of great value to Michigan producers. For example, cherry growers frequently find it difficult to meet the minimum size requirements set by canners, especially in years of drouth. Certain varieties of pears, as Bartlett and Kieffer, and of apples, as Yellow Transparent, Golden Delicious and Delicious often fail to reach the size most desired by the trade.

It was observed by Neal in 1944 (1) that when cherry trees were sprayed with an oil-wax emulsion the size of fruit was increased. These observations were confirmed in 1945 from other parts of the country (2) and by Neal in 1946 (3).

In order to secure information over a wider range of cultural and climatic conditions a series of field tests were undertaken in 1947 involving apples, pears, and sweet and sour cherries, the results of which are presented in this paper.

Methods and Materials

The emulsion used is known as Dow Wax 222, prepared commercially by the Dow Chemical Company of Midland, Michigan. Orchards in which the trials were conducted were in the commercial fruit area of western and eastern Michigan. The test blocks were treated in the same manner as the rest of the orchard of which they were a part, except for the addition of 1 per cent Dow Wax 222 as described in the following paragraph.

Cherries:—Sweet cherries, blocks I and II located 5 miles west of Fremont, Michigan, were sprayed with the emulsion, incorporated in the fungicide, and applied with a speed-sprayer. The trees were sprayed when the first sign of color appeared on the cherries and again a week later, opposite sides of the trees being sprayed each time making a complete coverage with two sprays.

The sour cherry orchard (orchard III) owned by John Langworthy and located on the Old Mission Peninsula in Grand Traverse County was sprayed with an emulsion of 1 per cent Dow Wax 222 incorporated with two different fungicides, namely Dithane and Tennessee

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The author wishes to express his appreciation to the Dow Chemical Company for the Dow Wax 222 used in this investigational work and to the following cooperating growers: Raymond Hyde, Hilltop Orchards, Fenton; Sidney Bender, Shelby; Theodore Rause, Shelby; John Langworthy, Old Mission Peninsula, Traverse City; William Hoppell, Suttons Bay; Circle Three Orchards (Hootman, Ricks, and Gaston) Fremont; and Ernest Langer, Jr., Benton Harbor. Especially appreciated is the assistance given by J. C. Kremer and Vernon J. Fisher of the Department of Horticulture, Michigan State College, in applying the oil-wax emulsion sprays and in obtaining records.

26. Sour cherry orchard IV was sprayed with the emulsion as a separate treatment. Both sour cherry blocks received two sprays. The first spray was made when pits had attained their full size and were half hard; the second spray was made at the time the first color appeared on the cherries. Orchards III and IV were on light sandy soils. Both orchards were sprayed with guns.

Cherry samples were obtained by picking three lots of 100 cherries from each tree for each treatment. Individual fruits were picked at random both from the ground-level and from the ladder. Each lot of 100 cherries was weighed immediately. The total weight of the 300 cherries was used for statistical analysis. In all orchards the circumferences of the tree trunks and the terminal growth was measured.

Because there was some question as to the sugar content and total solids content of the sprayed cherries, chemical analyses were made (see Table III).

Pears:—Two blocks of young Bartlett and Kieffer pears (orchards VI and VII) were sprayed with the emulsion. One group of trees in orchards VI and VII were sprayed at the second cover and again in mid-August. A second group was sprayed at pre-blossom, calyx, and second cover, mid-August, and first of September. A third group remained unsprayed as a check.

Apples:—Apple orchards VII, VIII, and IX were treated the same as the pear orchards. All emulsion sprays on pears and apples were applied independently of fungicidal sprays.

Records for both pears and apples were obtained by counting the number of fruits in a bushel. Apples were picked at random from each tree in each of the differently treated blocks and the average count for each treatment used for statistical analysis. The total crop from each treatment used for each block was graded and the percentage of fruits over 2¼ and under 2¼ inches was determined.

Temperatures and wind direction readings were made at the time of each spray application. The early part of the season was cold and rainy. Temperatures during the months of May and June were 60 to 65 degrees F for the most part, accompanied by rain 46 of the 61 days. Growth was succulent and susceptible to fungus attack.

Results and Discussion

The results with oil-wax emulsion sprays on the yield of cherries, pears and apples are shown in Tables I and II.

The increase in size of cherries was significant in every orchard treated.

Orchard I, Windsor Sweet Cherries:—As shown in Table I, the increase in size was greater than with any other orchard or variety. The increase of 23.6 per cent may seem at first glance to be a little large. It is true the treated trees averaged 4.8 inches larger in trunk circumference than the untreated trees, but to offset this difference the treated trees were carrying approximately 3,000 more cherries each. The average number of cherries per inch of trunk circumference was 668 for the treated as compared with 688 for the controls, which

TABLE I—EFFECT OF DOW WAX 222 ON THE SIZE AND YIELD OF BOTH SWEET AND SOUR CHERRIES

No. of Trees	Treatment	Average Weight 300 Cherries (Grams)	Average Circumference of Trunk (Inches)	Average Yield Per Tree (Pounds)	Number Cherries Per Tree Computed Average	Increase in Size (Per Cent)
	Windsor Orchard I					
5	First tinge of color and again one week later*	1,688	27.8	218	18,695	23.6
5		1,365	23.0	156	15,852	Control
	Black Tartarian Orchard II					
8	First tinge of color and again one week later*	1,467	26.0	95	9,026	14.0
8	None	1,287	25.8	88	9,548	Control
	Montmorency Orchard III					
8	First tinge of color and again 10 days later**	1,233	23.8	109	12,148	12.0
7	First tinge of color and again 10 days later†	1,167	22.9	99	11,614	7.0
5	None†	1,100	23.2	83	10,557	Control
	Montmorency Orchard IV					
8	Second cover and first tinge of color	1,123	33.2	169	20,837	7.5
	None	1,045	32.0	118	15,747	Control

*Application made from opposite sides of trees but in only one direction each time.
**Also received fungicide spray of Tennessee Copper 26.
†Also received fungicide spray of Dithane.

TABLE II—EFFECT OF DOW WAX 222 ON SIZE AND YIELD OF PEARS AND APPLES

No. of Tree	Treatment	Fruits Per Bushel (Average)	Bushels Per Tree (Average)	Size of Fruits (Per Cent)		Average Increase in Fruits 2¼ Inches and Up (Per Cent)
				2¼ Inches and Up	Under 2¼ Inches	
	Bartlett Pears (Orchard V)					
5	Second cover and mid-August	274	2.5	86.0	13.0	10
5	Complete*	256	2.3	91.5	8.5	16
3	None	283	2.7	75.7	24.7	Control
	Kieffer Pears (Orchard VI)					
5	Second cover and mid-August	271	1.4	87.5	12.5	-2
5	Complete*	216	1.6	95.0	5.0	5
4	None	264	1.8	89.7	10.3	Control
	Delicious Apples (Orchard VII)					
5	Second cover and mid-August	196	12.8	88.7	11.3	-1.3
5	Complete*	206	14.0	87.0	13.0	-3
5	None	171	9.3	90.0	10.0	Control
	Golden Delicious Apples (Orchard VIII)					
4	Second cover and mid-August	178	8.9	83.2	16.8	16
4	Complete*	276	7.0	60.0	40.0	-7
4	None	222	8.5	67.6	32.4	Control
3	Second cover and mid-August	223	16.0	67.0	33.0	-1.5
4	Complete*	196	5.8	88.0	12.0	19.0
4	None	221	10.6	68.5	31.5	Control

*Applications—complete coverage at calyx, first and second cover, mid-August, and mid-September.

brings the difference in crop load to only 20 cherries per inch of circumference. An especially good spray coverage was secured in this orchard because trees of this variety are characteristically open in growth habit, as compared to Black Tartarians.

Orchard II, Black Tartarian Sweet Cherries:—This variety showed an increase in size of 14 per cent. Both the treated and the control trees were about the same size, and were carrying approximately the same crop load. The total yield per tree in pounds was greater on the treated trees, so that it appears clear that the wax spray must have been the factor influencing the increase in size.

Orchard III, Montmorency Sour Cherries:—This is the block that received Tennessee Copper 26 as a fungicide in addition to the emulsion. The increase in size of fruit was 12 per cent. The trees treated with Dithane fungicide showed 7 per cent increase as compared to the controls. The size of the trees and the crop loads of fruit were comparable. In addition to the effect of the emulsion it appears that the fungicide may have had some influence in the proper functioning of the physiological processes of the tree.

Orchard IV, Montmorency Sour Cherries:—The uniformity in size of the trees in this orchard is shown in Table I by the variation of only .8 of an inch in trunk circumference. The larger of the treated trees averaged approximately 5,000 more cherries per tree or nearly two lugs. It is felt that this increase in number of cherries on the larger trees more than offset their large size, and probably accounts for the increase of only 7.5 per cent in size that was secured.

General:—There was no injury observed in any of the cherry orchards treated with wax. In orchard III, one untreated tree failed to mature its cherries to proper size for picking due to drouthy conditions. In addition, many other unsprayed trees in this orchard failed to mature the cherries to the size required by canneries.

Because there might be a difference in the quality of the larger cherries, several samples were picked and analyzed for sugar content and pit-flesh ratio. Table III shows that the difference in sugar content, though slight, was in favor of the treated cherries.

The larger cherries which resulted from wax sprays posed a problem for the processors. These cherries failed to take up water readily when soaked in water prior to sorting and pitting. The larger cherries were too large for the regular sour cherry pitter, and when pitted under these conditions came from the machine with ragged holes.

Orchard V, Six-Year-Old Bartlett Pear Trees:—The trees were growing in a clay loam soil where moisture was never a limiting factor. The trees that received a complete treatment with the emulsion ma-

TABLE III—ANALYSIS OF MONTMORENCY SOUR CHERRIES FOR SUGAR CONTENT

Sample	Total Sugar as Invert Sugar (Per Cent) Replicate Determinations			Averages	Titratable Acid as Ml 0.1 N. (Acid/Gram)	Pits (Per Cent)
Control	9.29	9.21	9.29	9.26	2.27	9.5
Sprayed	10.36	9.84	10.09	10.09	1.99	9.01

tured fruit of a larger size, with 10 to 16 per cent more of the pears above 2¼ inches than the check trees, as shown in Table II. The treated trees had better foliage, of brighter and more luxurious appearance. The fruit after grading and brushing was superior in finish, having a bright green under-color with slight blush.

Orchard VI, Kieffer Pears:—The fruit in this orchard showed little benefit from the emulsion sprays. Trees were the same age as the Bartlett trees in orchard V and they were growing on the same type soil. The lighter crop that these trees bore was reflected in the generally larger size of fruit, even without wax treatment. An early frost may also have affected development, inasmuch as the fruits did not increase in size after the frost.

Orchards VII, VIII, and IX, Delicious and Golden Delicious Apples:—Both Delicious and Golden Delicious failed to show any response from wax treatments. Additional contributing factor may have been the presence of red mites in sufficient numbers to bronze the foliage, very light droughty soils, and damage to the foliage and fruit by sun scald.

Summary and Conclusions

The use of Dow Wax 222 as a spray in Michigan orchards in 1947, applied to the fruit and foliage during the growing season resulted in an increase in size of fruit of 14 per cent for Black Tartarian sweet cherries, 23.6 per cent for Windsor sweet cherries, 7 to 12 per cent for Montmorency sour cherries, 10 to 16 per cent increase in Bartlett pears 2¼ inches and above, no increase for Kieffer pears, and no increase for Delicious and Golden Delicious apples.

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Respiration of Peach Leaves As Influenced By Some Spray Materials

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IT has been recognized for many years that spray materials had certain marked effects on the behavior of the leaves of trees. The gross effects of spray materials are readily recognized in dwarfed leaves, leaves which have been burned due to caustic materials and, in some cases, branches which have been markedly modified by spray materials. When such gross effects are apparent it has been obvious that the less visible physiological effects must take place and it seemed highly probable that many of these effects might be indicated by a change in respiration rate or in apparent photosynthesis.

With the extended development of the gross absorption method for the measurement of carbon dioxide by Heinicke and his co-workers, this matter was carefully investigated. It was found that frequently spray materials had marked effects upon apparent photosynthesis. Agnew and Childers (1) discovered that soluble sulphur sprays caused more injury than suspension forms when applied to plants. The soluble sulphurs caused the greatest reduction in apparent photosynthesis.

Christopher and others (2) made a careful study of the use of lime as a "safener" for other spray materials. They concluded that since lime did not appear to modify the rate of apparent photosynthesis either as an independent material or in the presence of other spray materials it could not be recommended for this purpose. Fossum and Laurie (3) and Laurie and Witt (4) reporting on a number of proprietary spray chemicals found that all of them markedly reduced apparent photosynthesis on application. The plants recovered more or less rapidly depending upon the material used. Pieniazek and Christopher (6) report that apparent photosynthesis is reduced by fermate and by lauryl pyridium chloride. Shutak and Christopher (8) report that Bordeaux has little effect on the respiration of tomato leaves.

Oberle *et al* (5) report a marked reduction in respiration when petroleum oils are used in sprays. When dinitro-phenolic materials are used with oils, respiration more nearly approaches normal indicating that the dinitro materials, if used alone, would seem to stimulate respiration.

Smock and Gross (7) discovered an interesting effect when using hormone sprays for the purpose of preventing apple drop. In general, they found respiration to be markedly increased after the spray materials had been applied for about 2 weeks, but that both earlier and later there appeared to be no particular stimulation of respiration.

In view of the very interesting work which has been carried on in this field it seemed desirable to extend the knowledge of the effect of spray materials on respiration as far as possible.

The problem of developing the complex equipment required for the Heinicke system was, for the time being, at least, beyond the reach of this laboratory. A study of the various method of measuring respiration indicated that a Warburg manometric method came the closest

to meeting the limitations of the laboratory and at the same time meeting the technical requirements of the problem at hand.

Four different materials were studied; lead arsenate, lead arsenate plus zinc sulphate, DDT, and rothane. In general, the results of the study were quite satisfactory insofar as the instrument was concerned. From the standpoint of results, with reference to the spray materials, however, in too many cases the results were disappointing. A number of particular cases, however, can be brought out to indicate, first, that the apparatus is adaptable to the problem and, second, that the results obtained are well within the limits of acceptable error when the apparatus is correctly used. The best work that was done during the summer was with DDT as compared with benzenehexachloride and with rothane.

It is to be noted in Table I that the respiration of young leaves was markedly modified by the materials applied. The respiration of the oldest leaves on the shoot was little affected by any of the materials.

TABLE I—EFFECT OF SOME SPRAY MATERIALS ON OXYGEN CONSUMPTION BY PEACH LEAVES

Treatment	Rate of Application (Lbs Per 100 Gal)	No. Observations	Oldest Leaves	Mid-Stem Leaves	Youngest Leaves
50 per cent DDT*.....	2	50	0.00**	+0.23	+0.25
25 per cent DDD....	4	10	−0.05	−0.10	−0.65
50 per cent BHC......	4	10	+0.02	−0.13	+0.17
Pb and Zn...........	4 4	5	−0.02	−0.10	−0.63
Pb.................	4	5	+0.05	−0.45	−0.75

*DDT—Dichloro-Diphenyl, trichloro-ethane.
DDD—Dichloro-Diphenyl, dichloro-ethane.
BHC—Benzenehexachloride, 10 per cent gamma isomer, (.2 pounds per 100 gallons).
Pb—Lead arsenate.
Zn—Zinc sulphate.

**Difference in consumption of O_2 in cc per gram dry matter per hour between treated and untreated leaves of the same class.

Data are not corrected for barometric pressure or temperature. Average temperature during experiment 23 to 28 degrees C.

Leaves which were taken from the central part of the stem and which in July and August were expected to be most active in photosynthesis and moderately active in respiration frequently showed repressed respiration rates as compared with those leaves which were not treated. A second interesting point found in these data is the speed with which the applied materials are effective in changing the rate of respiration. It was found that in order to use the Warburg apparatus satisfactorily the respiration chambers had to be set up for an hour before the first readings were taken. By this time the spray materials had already begun to modify metabolism of the leaves.

The results obtained for lead arsenate and for lead arsenate and zinc seemed to indicate that when zinc was applied with the lead arsenate respiration was depressed less than when lead arsenate was applied alone. This information has some confirmation in other work, but the differences are not significant in this test.

Both rothane and benzenehexachloride appear to have less effect on respiration than does DDT. This, however, will require still further study.

Summary

It was found that a modification of the Warburg manometric system for tissue respiration could be used for samples of leaves or other plant parts of moderate size. This system was used to test the effect of some spray materials on the respiration of peach leaves. The results obtained in these particular tests are generally in line with other work on the respiration of leaves of horticultural plants. DDT appears to have its major effect on the respiration of the youngest leaves, in which case a marked increase in respiration is apparent. On leaves which appear to be fully mature and completely functional, DDT seems to have a depressing effect. The respiration of basal leaves is little affected. Lead arsenate when applied with zinc sulphate seems to depress respiration less than does lead arsenate alone.

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Boron Deficiency in Apricots[1]

By R. M. BULLOCK and N. R. BENSON, *Tree Fruit Experiment Station, Wenatchee, Wash.*

APRICOTS, produced in certain orchards in the Wenatchee Valley of Washington during recent years, have shown fruit malformations that have made the affected fruit unmarketable. During the 1946 season, several orchards produced fruit that was severely cracked. In other orchards, the fruit was shriveled, deformed and discolored with internal browning and corky tissue developing near the stone. These symptoms were found even more widely distributed in the 1947 season.

In New Zealand, a browning of the flesh of apricots, more particularly in the stem end of the fruit, has been shown by Askew and Williams (1) to be due to boron deficiency. This condition was controlled by the use of hydrated borax either as a soil top dressing or as a spray. The marked increase in boron content of the fruit following borax treatment was correlated positively with freedom from browning of the flesh. Drought spot of apricots from boron deficiency has been reported in British Columbia by Greenhill (5).

Fitzpatrick and Woodbridge (4) reported that the symptoms of boron deficiency in the fruit of apricots as described by Askew and Williams (1) have been observed in a few orchards in the Okanogan district of British Columbia, and have responded to soil applications of boric acid. Tree symptoms for boron deficiency in apricots were also described.

FRUIT SYMPTOMS

In the Wenatchee area, apricot fruits affected by boron deficiency have been found to exhibit three definite symptoms, any one of which may occur singly or in any combination with the other two. These three symptoms are:

1. Internal browning and formation of corky tissue around the stone cavity and extending into the flesh to varying distances, depending on the severity or stage of development of the deficiency. Cork cells may also appear in the flesh not adjacent to the stone. Early in the development of this symptom, the corky cells appear in small flecks, while later, the entire area around the stone turns brown and becomes dry and spongy in nature. This condition most commonly appears in connection with either of the two following symptoms as shown in Figs. 1 and 3.

2. Cracking of the fruit is positively correlated with a low boron content. The cracks appear most often longitudinally in the fruit, irrespective of the suture line; they may occur as transverse cracks or very irregular cracks on the sides of the fruit. They commonly extend into the flesh a distance of one-third to one-quarter of its thickness and are dry and corky. The cracks vary in length from less than 1 to more than 3 centimeters. In severe cases, they extend over much of the fruit

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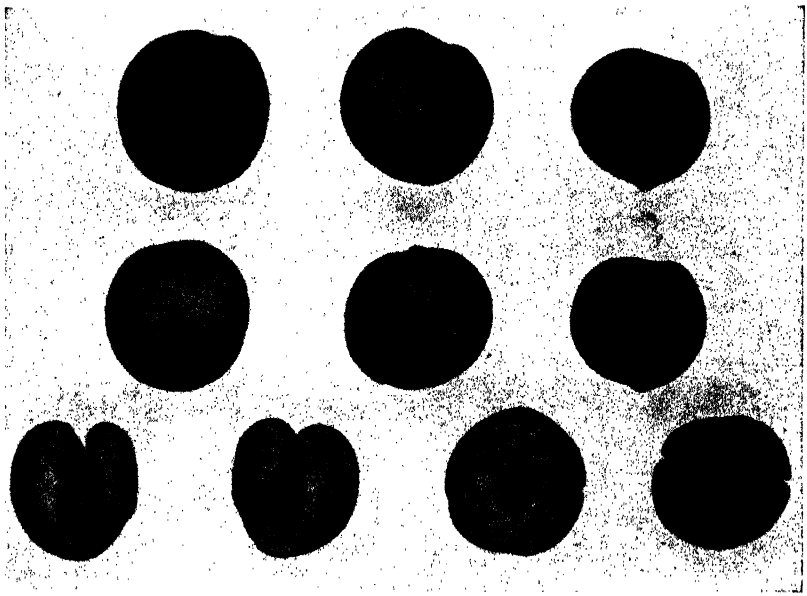

FIG. 1. Boron deficient apricots showing surface browning on the left and fruit cracking on the right.

circumference. Several may occur on the same fruit as shown in Figs. 1 and 4.

Small cracks (Fig. 2) have been observed that seldom exceed a few millimeters in length and penetrate no deeper than the skin. These have not been correlated, as yet, with the boron content of the fruit.

Cracking is most commonly associated with internal browning or corky areas near the stone cavity, and may be found with shriveling of the fruit as described in No. 3.

3. A large shriveled area on the surface of the fruit and acute malformation of the fruit (Fig. 3) have been positively correlated with a low boron content of the fruit. The shriveled area may occur at any point and usually causes an acute constriction in the shape of the fruit. These areas become deep brown in color and extend toward the center of the fruit as ripening progresses. This symptom, as well as cracking, is usually in association with the internal browning, and in severe cases, the two corky and brown areas join, making the entire fruit malformed.

A condition observed in boron deficient orchards was a differential ripening within each fruit. The flesh ripened near the stone prematurely separating from the stone and the ripening progressed toward the outside through about half the thickness of the flesh. The outer half of the flesh failed to ripen normally remaining hard and green until after harvest when shriveling occurred instead of normal ripening. These fruits were not analyzed for boron, but other fruits from this orchard were very deficient. This condition failed to appear on trees where boron was applied, but did appear on untreated trees in the same orchard.

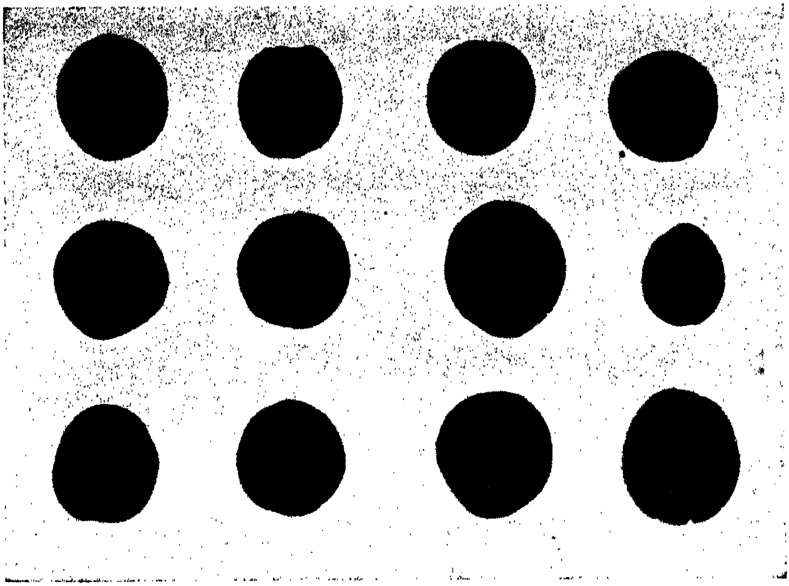

FIG. 2. Small skin checks and necrotic spot on apricot fruit.

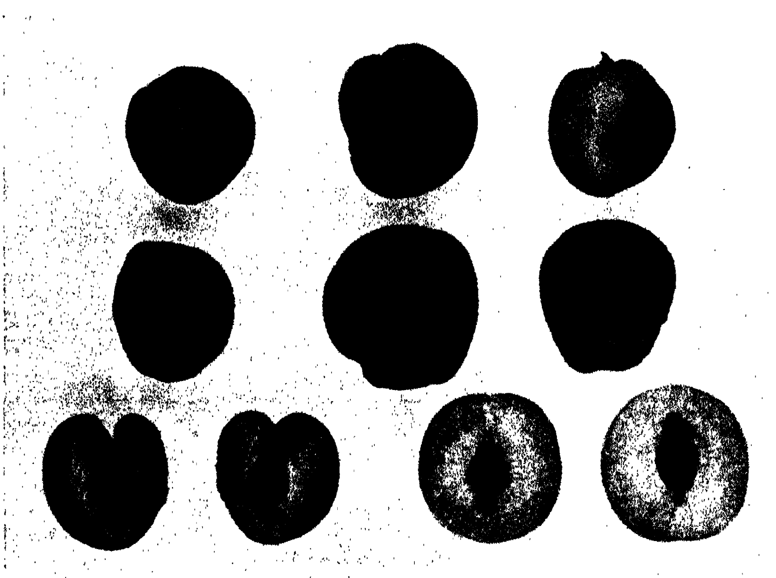

FIG. 3. Apricot fruit showing surface browning, (upper left); internal browning (lower left); cork formation early (lower right); and advanced (lower left); shrivelling (right center); and constrictions causing fruit malformations (center).

FIG. 4. Comparison of apricot fruit following treatment with borax with those receiving no borax.

Dark necrotic spots, as shown in the top row of Fig. 2 have not been associated with a shortage of boron. Analysis of these fruits have shown them to be the highest in boron content of any in the Wenatchee area, even though they have not received any applications of boron. Eaton *et al* (3) describes a similar condition as boron toxicity.

TREATMENTS

During the season of 1946 when these disorders in apricots were brought to the attention of the authors, soil applications of borax were made at the rate of ½ pound per tree to four trees in two different orchards showing the symptoms described above.

The fruit produced on all of the trees treated with borax in 1946 were free of any of the symptoms in 1947, while the untreated trees again produced fruit showing all of the symptoms as shown in Figs. 1 and 3.

Fruit and leaves were gathered from several areas in the north central Washington district during the 1947 season for boron analysis. All samples were prepared for analysis by drying at 60 degrees C. The method of Berger and Truog (2) was used for analysis. These data, reported on the dry weight basis, are shown in Table I.

Apricots that showed boron deficiency symptoms varied from 9 to 18 pppm boron in the fruit. Boron in the leaves from these trees varied from 32 to 50 ppm. Apricots that did not show boron deficiency symp-

TABLE I—BORON CONTENT OF APRICOT FRUIT AND LEAVES

Condition of Fruit	Location	Variety	Analysis* (Ppm Boron)	
			Fruit	Leaves
Shriveled	Malaga	Moorpark	10	32
Shriveled	East Wenatchee	Moorpark	12	—
Flesh cracks	East Wenatchee	Tilton	9	43
Flesh cracks	East Wenatchee	Moorpark	18	43
Flesh cracks	Manson	Moorpark	13	50
Flesh cracks	Malaga	Moorpark	18	32
Shallow skin cracks	Orondo	Moorpark	132	53
Necrotic spots	Wenatchee	Moorpark	205	—
Normal	———	Moorpark	30	—
Normal plus boron**	East Wenatchee	Tilton	150	73
Normal plus boron**	East Wenatchee	Moorpark	130	73

*Average of three determinations.
**8 ounces borax added per tree.

toms contained 30 ppm. Where boron was added to the soil at the rate of ½ pound borax per tree, the fruit contained 130 to 150 ppm and the leaves contained 73 ppm boron. This striking increase in boron in the treated trees correlates positively with the production of unblemished fruit as shown in Fig. 4.

There is a consistent difference between the boron content of normal fruit and of fruit showing symptoms here described as being boron deficient. The boron content of the leaves is rather constant over the ranges sampled as may be expected since no vegetative symptoms of boron deficiency were found in any of the areas sampled, even where the boron content of the fruit was as low as 9 ppm. The tendency for boron to accumulate in the leaves is not as great as it is in the fruit, since the boron content of the fruit reached 150 ppm, while that of the leaves reached only 73 ppm where boron was added to light sandy soil. This is in accordance with Eaton's *et al* (3) report that boron is not accumulated in the leaves of stone fruits, but is accumulated in the bark and fruit of stone fruits.

SUMMARY

1. During recent years, fruit malformations of apricots making the fruit unmarketable, have become increasingly evident in the Wenatchee area of Washington.

2. These malformations occur as three distinct symptoms: (a) Internal browning and corky tissue developing in the stone area. (b) Cracking of the fruit. (c) Shriveling, surface browning, and constrictions of fruit.

3. Field applications of ½ pound borax per tree have corrected all three symptoms.

4. Boron content of apricot leaves does not fluctuate as widely as that of the fruit.

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The Effectiveness of Some Organic Mulches in Correcting Potassium Deficiency in Peach Trees on a Sandy Soil[1]

By Clarence E. Baker, *Purdue University Agricultural Experiment Station, Lafayette, Ind.*

The effect of mulches upon the potassium content of apple and peach leaves has been discussed previously (1, 2). Those studies showed that strawy manure, straw, and other organic mulches resulted in considerably increased amounts of potassium in leaves from the median portion of terminal shoots of apple trees, in comparison with leaves from unmulched trees in cultivation or sod. Similarly, in the case of peach trees, on both clay and sandy loam soils, the use of straw or alfalfa as a mulch about the trees caused an increase in the potassium content of the foliage.

In the above comparisons, which were made in connection with soil management studies, potassium deficiencies were not involved. The lowest levels of potassium encountered were well above those generally associated with a deficiency condition. The trees in the orchards in which these investigations were conducted were making good growth and exhibited no foliar nutrient deficiency symptoms, even in the less favorably treated plots, with the exception of one obvious case of nitrogen starvation in an apple orchard.

Methods

In the spring of 1946 our attention was called to a young apple orchard with peach filler trees located in the extreme northern part of Indiana, about 6 miles south of Lake Michigan, where a potassium starvation condition appeared to be present on the peach trees. This planting was on a Coloma loamy fine sand with a rolling terrain. Some gravel was present in spots in the low areas. The land had been in alfalfa for several years and had been heavily limed previously.

The orchard was set in the spring of 1945 and many of the peach trees (Red Haven) showed an abnormal foliage condition during the summer, which the owner recognized as potassium starvation. In the spring of 1946 he treated about two-thirds of the orchard, both peach and apple trees, by injecting a solution of KCl containing about 2 pounds of KCl (0–0–50) per gallon of water into the soil about and below the roots. The solution was applied with a power sprayer through a ¼-inch pipe welded into a spray gun. Each tree received, on the average, an application of KCl equivalent to approximately 6 pounds of 0–0–50. Unfortunately, this was too heavy an application and 37 per cent of the apple trees and 54 per cent of the peach trees died within a few weeks, presumably from the high salt concentration. Solutions for this purpose usually contain ½ pound of KCl per gallon of water and an application equivalent to 2 pounds of 0–0–50 per tree or less is used on trees of this age.

[1]Journal Paper No. 330 Purdue University Agricultural Experiment Station.

Plans were made to conduct some mulching studies in the untreated part of the orchard. Tests of the untreated soil showed a very low potassium level and a pH of 6.6 to 6.8. As the potassium deficiency was not expected to be uniform over the area and as the foliage symptoms do not become well developed before July, it was necessary to wait until late summer to select the experimental trees.

In early September, 1946, mulches of straw, soybean hay, and manure were applied to peach trees that had developed definite potassium starvation symptoms. About two bales of straw or soybean hay were used around each tree and the manure was applied in a 4-inch layer over a circle about 8 feet in diameter. Trees were selected that showed potassium starvation symptoms to about the same degree and that were as uniform as possible in size, but the various mulching materials were applied to trees scattered at random. Untreated check trees were left near each mulched group. Representative trees in each treatment were photographed on Kodachrome for record purposes soon after the mulches were applied.

An application of 5 pounds of KCl (0–0–60) was made on September 11, 1946, to several of the trees mulched with straw and soybean hay, broadcasting the fertilizer on top of the mulch.

Surviving peach trees in the part of the orchard that had received the heavy KCl treatment developed no potassium starvation symptoms during the summer of 1946. Some of these trees appeared to be still suffering from a high salt concentration.

Each tree in the orchard received about 1 pound of ammonium nitrate in the spring of 1946 and in the spring of 1947.

Results

The mulched trees made a very definite recovery during the 1947 season. Regardless of the material used, all the mulched trees made excellent growth and appeared to be vigorous in every way. The leaves were normal size and shape with a healthy dark green color. The trees made a good total amount of growth for peach trees in their third growing season. They were, of course, smaller than the trees that had not experienced potassium starvation, as all of the trees now mulched had made very poor growth during their first two growing seasons.

All of the unmulched check trees again developed definite potassium starvation symptoms during the summer of 1947 and made very poor growth in comparison with the mulched trees. Most of the check trees had lost much of their discolored foliage by late September, while the mulched trees, and the other vigorous trees in the orchard, had lost few leaves at the time of the first hard frost in early November. The trees mulched with manure began to show improvement in the condition of their foliage in 1946, between the time the mulch was added in early September and leaf fall in late October.

The application of potash to the mulched trees proved to be unnecessary as the mulches appeared to correct the deficiency without the addition of potassium in the chemical form.

Leaf Analyses

Analyses of leaves from the median portion of terminal shoots made on samples taken in September, 1946 and September, 1947, when the starvation symptoms were at the maximum level, show the potassium values for the different treatments set out in Table I.

TABLE I—The Effect of Various Mulches on the Potassium Content of Leaves From Terminal Shoots (Bassett Peach Orchard)

	K as Per Cent of Dry Weight	
	September 1946	September 1947
Untreated K starved trees	0.26**	0.33
KCl (0 0 50) 1946*	0.97	1.74
Manure mulch (Fall 1946)	0.26**	2.58
Soybean hay mulch (Fall 1946)	0.26**	1.83
Straw mulch (Fall 1946)	0.26**	1.93
Normal untreated trees	0.68	—†

*About 6 pounds per tree in solution injected into soil about roots (Spring of second growing season).
**Composite sample from leaves of K starved untreated trees before mulching.
†Mulched by owner Fall of 1946.

Discussion

The leaves generally had a low potassium level in 1946. The figure 0.26 per cent for the untreated trees in 1946 is based upon a composite sample including leaves from about one-half of the potassium starved trees. Leaves from trees surviving the heavy application of KCl showed less than 1.0 per cent potassium in September 1946. It is possible that the surviving trees received a much reduced amount of KCl in comparison with the trees that were killed, or that much of the fertilizer was placed well below the roots where some of it leached away before the tree roots reached that depth. In May, 1946, the young leaves of these heavily treated trees contained 2.04 per cent potassium in comparison with 1.22 per cent for similar leaves from untreated trees.

In September, 1947, leaves from unmulched check trees had approximately the same potassium level (0.33 per cent) as in September, 1946 (0.26 per cent) and exhibited about the same degree of potassium starvation symptoms. The various mulches all increased the amount of potassium in the leaves very greatly. Manure was the most effective in that respect, with straw and soybean hay mulches exerting important, but lesser effect. Soil tests, likewise, indicate a greatly increased amount of potassium in the root zone beneath all of the mulches. The trees that survived the heavy application of KCl in 1946 had more potassium in their leaves in 1947 than in 1946. This seems to support the idea that they survived the heavy treatment because the fertilizer solution was placed below the main root zone where the young tree did not reach it until the 1947 growing season. By that time the concentration would have been greatly reduced. The killing of many of the young roots that grew deeply enough in 1946 to reach the high salt concentration before they could absorb much potassium, might be another explanation.

The young apple trees in this same planting, where many of the peach trees showed evidence of severe potassium starvation, failed to exhibit any definite foliage abnormalities and made what appeared to be normal growth. The small amount of leaf injury occasionally found on the apple trees seemed more likely to be the results of spray applications or insect infestation than to be caused by nutrient deficiencies. This is another example of the differential requirements between peach and apple trees for potassium. In this orchard apple trees appear to be making normal growth on soil with an available potassium level so low for peach trees that serious foliar symptoms and greatly restricted growth results.

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Interrelationship Between the Nutrient Content of Soil, Leaves, and Trunk Circumference of Peach Trees[1]

By A. L. KENWORTHY, *Michigan State College, East Lansing, Mich.*, and G. M. GILLIGAN, *Delaware Agricultural Experiment Station, Newark, Del.*

AN orchard of Halehaven peaches was planted in 1941 at the Sub-station, near Georgetown, Delaware. This orchard was planted on a Sassafras sandy loam of low fertility and organic carbon content, and has been given differential cover crop and fertilizer treatments since planting. Soil and leaf analyses were made on these plots at the end of the 1946 growing season. From these analyses and trunk circumference measurements, certain correlations were found to exist between the nitrogen, phosphorus, and potassium contents of the leaves, and available phosphorus, exchangeable potassium and organic carbon content of the soil and trunk circumference. This paper deals with these correlations. The effects of the various cover crop and fertilizer program will be included in a separate publication.

REVIEW OF LITERATURE

Attempts to work out the correlation of leaf analysis, soil analysis and tree growth of peach trees are relatively few. Davidson and Blake (3) reported that high calcium in a nutrient solution resulted in a decrease in soluble potassium and an increase in soluble phosphorus in peach leaves; while high potassium in a nutrient solution resulted in a decrease in soluble potassium and an increase in soluble phosphorus. According to Lilleland and Brown (7) an increase in leaf potassium resulted in a reduction in calcium and magnesium. They also found a positive relationship between soil and leaf potassium until the soil contained 200 parts per million beyond which there was no further increase in leaf potassium. Omission of phosphorus from fertilizers was found by Scott (8) to result in decreased tree growth and production.

Peach tree growth and yield of fruit were not proportional to total or undecomposed soil organic matter in Wooster silt loam according to Judkins and Wander (5).

Nitrogen, potassium, and phosphorus content of apple leaves was found to be proportional to supply by Batjer, Baynes, and Regeimbal (1). The potassium level had no significant effect on nitrogen content of the leaves but decreasing nitrogen was associated with increased leaf potassium. The phosphorus level had no effect on leaf potassium.

Shear (10) reported that nitrate applications alone or in combination with phosphorus and potash resulted in increased nitrogen content of the leaf but did not affect the phosphorus or potassium content.

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The work reported here was conducted while the senior author was with the Delaware Agricultural Experiment Station.

As a general conclusion from sand culture studies on peach trees with varying concentrations of nitrogen, phosphorus, potassium, and calcium, Brown (2) stated that "fundamentally, each element was antagonistic, at least potentially, to the accumulation of each of the others within the top of the trees". He found that phosphorus had a strong repressive action on nitrogen; nitrogen on potassium, calcium, and magnesium; and calcium on nitrogen, phosphorus, potassium, and magnesium. The antagonistic action varied with the tissue under consideration. Several interrelationships between the elements' antagonistic action were also observed.

PROCEDURE

The leaves were collected from the peach trees on September 4, 1946, and dried at 70 degrees C. Leaves medial on the shoots were used. They were ground and analyzed for nitrogen, phosphorus, and potassium. The soil samples were collected on the same date from the upper 6 inches of soil, air-dried, screened, pH determined, and analyzed for available phosphorus, exchangeable potassium, and organic carbon. Forty-eight samples each, of leaf and soil were collected and analyzed. The values obtained were then submitted to simple and multiple correlation studies. Two of the 12 treatments involved had broiler manure substituted for sodium nitrate applications to the tree. The values used in the correlation studies were expressed as percentage of leaf nitrogen, phosphorus, and potassium; as parts per million available phosphorus; exchangeable potassium as milligram per 100 gram; and as percentage of organic carbon.

RESULTS OF CORRELATION STUDIES

Leaf Analysis:—Since the treatments in which broiler manure was substituted for nitrate applications affected the nitrogen, phosphorus, and potassium values, correlations were made on the two groups separately.

The correlation between leaf nitrogen and leaf potassium was highly significant ($r = +0.416$; $E_k = 0.534\ N + 0.51$ — Snedecor (11)) for the nitrate treatments while the correlation for the broiler manure treatments was not significant. A scattered diagram, however, showed that there was a negative trend indicating that higher potassium content tends to depress nitrogen absorption.

The correlation between leaf nitrogen and leaf phosphorus for the nitrate plots was highly significant ($r = +0.782$; $E_p = 0.115\ N - 0.233$) as shown in Fig. 1 when the phosphorus content was low (less than 0.25 per cent). However, there was a significant negative correlation ($r = -0.756$; $E_p = 1.33 - 0.36\ N$) between leaf nitrogen and phosphorus when the phosphorus content was high (over 0.25 per cent).

The regression lines in Fig. 1 fail to intersect at the apex (phosphorus 0.25 per cent — nitrogen 4.0 per cent) and is doubtlessly due to the depressing effects of other nutrients such as potassium, magnesium, calcium, and so on, upon the absorption of nitrogen. As indicated by Brown (2) and Shear, Crane, and Myers (9), nitrogen

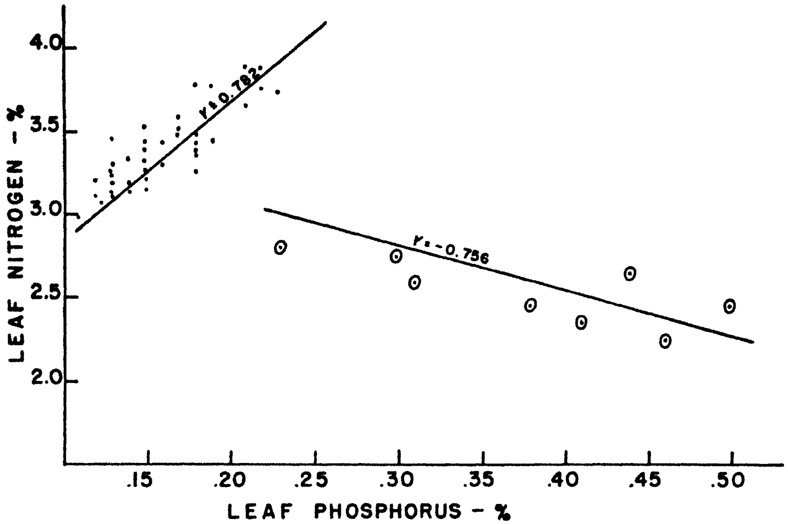

FIG. 1. Correlation and regression between leaf nitrogen and leaf phosphorus (Circled numbers from broiler manure plots).

and phosphorus should not be considered alone since other nutrients may easily affect the relationship of two elements. Lilleland (6) suggested that higher phosphorus content of the leaf tends to depress nitrogen absorption as shown in Fig. 1 while Brown (2) found that increased phosphorus in sand culture depressed nitrogen in shoots and trunks of peach trees.

The correlation between leaf phosphorus and leaf potassium, according to Fig. 2 was highly significant ($r = 0.41$; $E_k = 3.57\ P + 1.77$)

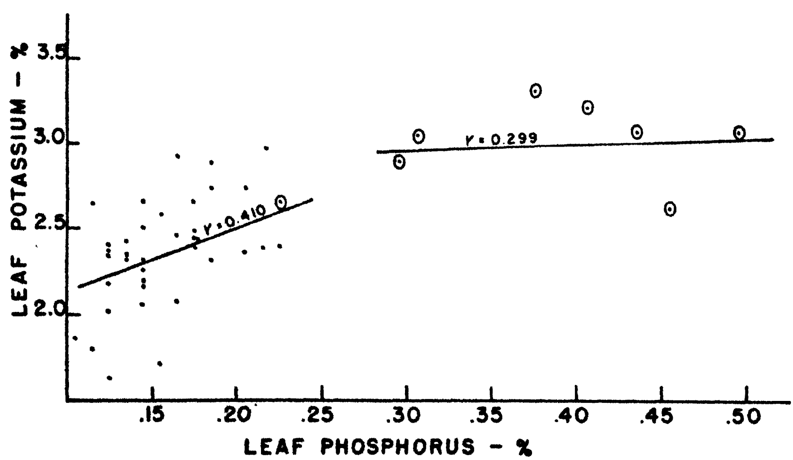

FIG. 2. Correlation and regression between leaf potassium and leaf phosphorus (Circled values from broiler manure plots).

when the values from the broiler manure plots were omitted. The correlation for the broiler manure plots was non-significant ($r = 0.299$).

The regression line for the broiler manure plots is shown in Fig. 2 because of its slope in relation to the slope of the regression line for the nitrate plots. As shown in Fig. 2, the amount of potassium in peach leaves increases as the phosphorus increases until the level of potassium reaches approximately 3.0 per cent at which point the potassium content of peach leaves appears to level off. However, Brown (2) reported potassium contents for peach trees well above 3.5 per cent resulting from a high level of potassium thus indicating that there would have been continued absorption had it been available. The decrease in rate of absorption of potassium seems to occur also when the phosphorus content is between 0.25 and 0.30 per cent.

Soil Analysis:—Soil pH was significantly correlated with organic carbon ($r = 0.603$; $E_{o.c.} = 0.68\ pH - 3.47$) while there was no correlation with available phosphorus or exchangeable potassium. Available phosphorus was significantly correlated with exchangeable potassium ($r = 0.461$; $E_k = 0.096\ P + 2.73$) and organic carbon ($r = 0.308$; $E_{o.c.} = 0.00096\ P + 0.382$). Exchangeable potassium was significantly correlated with organic carbon ($r = 0.656$; $E_{o.c.} = 0.099\ K + 0.03$). All other correlations potentially possible between these values were found to be non-significant. Scattered diagrams of the correlated values indicated a wide fluctuation with a soil variation in that the soil containing finer particles contained more organic carbon but considerably more available phosphorus and exchangeable potassium. Apparently from the above correlations organic carbon was most influential in affecting the concentration of other nutrients. This is borne out by the results of other studies on Delaware soils (4) in which a highly significant correlation was found to exist between organic carbon and exchange capacity and consequently available nutrients.

Leaf Analysis with Soil Analysis:—Attempts to correlate leaf analysis with soil analysis showed that leaf phosphorus was not significantly correlated with available phosphorus. Organic carbon and leaf nitrogen was significantly correlated ($r=0.309$; $E_n=412\ O.C.+1.33$). Exchangeable potassium and leaf potassium was significantly correlated ($r = 0.489$; $E_{l.k.} = 0.051\ E.\ K. + 2.08$). The slope of the regression lines indicate that a small increase in organic carbon of the soil results in a marked increase in leaf nitrogen while a large increase in exchangeable potassium is necessary to bring about a marked increase in leaf potassium. The positive correlation between leaf potassium and exchangeable potassium is in agreement with the findings of Lilleland and Brown (7) since all values for exchangeable potassium were below 200 parts per million.

Leaf and Soil Analysis With Trunk Circumference:—A significant correlation was found between leaf nitrogen for the nitrate plots and trunk circumference ($r = 0.351$; $E_{t.c.} = 3.78\ N + 15.93$). Leaf potassium was not significantly correlated with trunk circumference. However, leaf phosphorus was significantly correlated with trunk circumference as shown in Fig. 3.

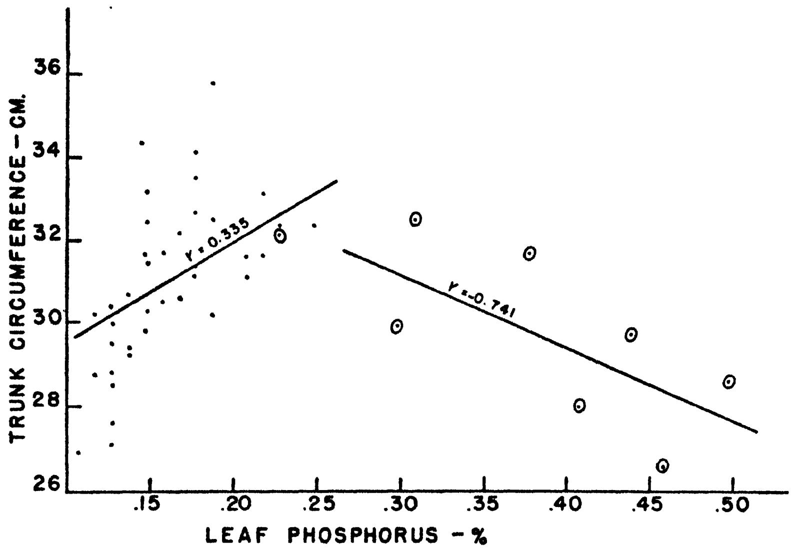

FIG. 3. Correlation and regression between leaf phosphorus and trunk circumference (Circled values from broiler manure plots).

According to Fig. 3, leaf phosphorus for the nitrate plots was significantly correlated ($r = 0.335$; $E_{t.c.} = 24.25\ P + 25.00$) with trunk circumference. A reversal of the sign of coefficient was found with the broiler manure plots ($r = -0.741$; $E_{t.c.} = 34.19 - 16.98\ P$). The intersection of the regression lines in Fig. 3 indicates that when leaf phosphorus is above 0.225 per cent the rate of tree growth decreases. Whether this effect is due to high phosphorus alone or to the effect of high phosphorus upon nitrogen absorption is a matter of speculation. However, since all trees received an equal amount of nitrogen, the authors believe that the high phosphorus level depresses nitrogen utilization or absorption and consequently has a depressing effect on rate of growth. Such interpretation is in accord with the findings of Brown (2).

Soil pH, available phosphorus, and exchangeable potassium were not significantly correlated with trunk circumference while organic carbon was ($r = 0.878$; $E_{t.c.} = 6.84$ O. C. $+ 25.4$).

DISCUSSION

The action of leaf phosphorus in relation to leaf nitrogen and tree growth is extremely interesting in view of the general opinion that soil applications of phosphorus seldom increase the phosphorus content of the foliage. Such a behavior for phosphorus may be more pronounced in soils having a higher fixing power than the soil used in this study which was very low in fixing power and, therefore, whatever soluble fertilizers were applied became available to the trees immediately. This lack of fixation of phosphorus partially explains the

luxury absorption of phosphorus and its antagonistic action upon the absorption of nitrogen and tree growth.

From these correlation studies, there appears to be a positive relationship between nitrogen, phosphorus, and potassium in peach leaves until a certain level of nutrition is reached beyond which there appears to be a reduction in rate of absorption of potassium while higher phosphorus levels exert an antagonistic action upon the absorption of nitrogen and upon tree growth. There was an indication that higher potassium absorption may also depress nitrogen absorption and from the intersection of the nitrogen-phosphorus regression lines it is assumed that other elements may also have such an influence.

In the sandy soils used for this study, organic carbon appears to be the most influential factor. With increased organic carbon, there results potential increases in other nutrients. Apparently, relatively small increases in organic carbon have very pronounced effects upon available phosphorus, exchangeable potassium, and tree growth because most of the values found in this study were within the range of 0.25 to 0.60 per cent.

Summary

The following positive correlations were found to be significant:

1. Leaf nitrogen with leaf potassium.
2. Leaf nitrogen with low leaf phosphorus (below 0.25 per cent).
3. Leaf potassium with low leaf phosphorus (below 0.25 to 0.30 per cent).
4. Soil pH with organic carbon.
5. Available phosphorus with organic carbon.
6. Available phosphorus with exchangeable potassium.
7. Exchangeable potassium with organic carbon.
8. Leaf nitrogen with organic carbon.
9. Exchangeable potassium with leaf potassium.
10. Leaf nitrogen and trunk circumference.
11. Trunk circumference with low leaf phosphorus (below 0.225 per cent).
12. Organic carbon with trunk circumference.

The following negative correlations were found to be significant:

1. Leaf nitrogen and high leaf phosphorus (above 0.25 per cent).
2. Trunk circumference with high leaf phosphorus (above 0.225 per cent).

The rate of potassium absorption by leaves is reduced when the phosphorus content exceeds 0.30 per cent.

High phosphorus content of peach leaves depresses nitrogen absorption. Organic carbon appears to have the greatest influence on peach tree nitrition and growth in sandy soils.

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Peach Leaf Color as an Indicator of Fruit Flesh Color

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PEACH leaves have turned yellow and abscissed during the growing season as observed in the experimental orchards at Blacksburg during the past several years. There has been varietal difference in the shade of yellow coloring of these fallen leaves. Leaves from yellow-fleshed varieties have been of an orange yellow color, while those of white-fleshed varieties have been of a pale yellow color. HofMann (1) mentioned this association.

METHODS

From 1944 to 1947 color records were obtained of leaf and fruit flesh color, in which Maerz and Paul's Dictionary of Color (2) served as a guide to the shades of coloring. A large number of seedlings and varieties were observed. In the earlier records certain inconsistencies occurred. In 1947, however, it was found that these cases could be attributed to variations in the growth and certain other factors.

Leaf samples were obtained from the inner parts of the trees, since exposure to bright sunlight tended to encourage the development of a red overcolor that masked the characteristic yellow leaf color of certain varieties and seedlings.

These yellow leaves were gathered at the abscissional stage. If gathered too soon there was a greenish coloration on parts of the leaves. On the other hand, after the leaves had fallen, the yellow color tended to fade.

RESULTS

Matching the leaf colors with color plates of Maerz and Paul (2) determined that leaf colors ranging from 9–H–1 to 9–J–1 (pale yellow) were obtained from trees bearing white-fleshed fruit. When the leaves matched with 9–K–1, 9–L–1, or 9–L–2 usually an intermediate creamy-white-fleshed fruit was found, although this classification was more difficult than the other two. Leaf colors from 9–L–5 to 9–L–9 (deep yellow) were obtained from varieties or seedlings producing yellow-fleshed fruit.

Among 525 seedlings that were sampled there was no inconsistency in this relationship between leaf-color and fruit flesh as it applied to either white-fleshed or yellow-fleshed seedlings. The limits of leaf colors for the intermediate creamy-white-fleshed coloration, however, were a little obscure in some instances.

Among 87 peach varieties that were replicated four times the same relationships existed as for the seedlings. Table I lists a few well known varieties, together with their leaf and fruit colors.

Tree vigor affected the yellow leaf color. On trees of low vigor, there was a decided reddish or brownish overcolor that darkened and dulled the characteristic yellow leaf color. On excessively vigorous trees the overcolor was greenish yellow.

The reddish overcolor was very pronounced on the yellow leaves of

TABLE I—PEACH VARIETIES WITH THEIR RESPECTIVE LEAF COLORS AND FRUIT FLESH COLORS

Variety	Leaf Color	Fruit Flesh Color
Ambergem	9-L-7 to 9-L-8	Yellow
Dixigem	9-L-5 to 9-L-7	Yellow
Dixired	9-L-5 to 9-L-7	Yellow
Elberta	9-L-6 to 9-L-8	Yellow
Fisher	9-L-6 to 9-L-7	Yellow
Golden Jubilee	9-L-5 to 9-L-7	Yellow
Halberta	9-L-8	Yellow
Halehaven	9-L-6 to 9-L-7	Yellow
J. H. Hale	9-L-6 to 9-L-7	Yellow
July Elberta	9-L-6 to 9-L-7	Yellow
Lizzie	9-L-5 to 9-L-7	Yellow
Rio-Oso-Gem	9-L-7	Yellow
Shipper's Late Red	9-L-7 to 9-L-8	Yellow
South Haven	9-L-5 to 9-L-7	Yellow
Sullivan's Early Elberta	9-L-6 to 9-L-8	Yellow
Belle of Georgia	9-I-1 to 9-L-1	White
Best May	9-L-1 to 9-L-2	Creamy-white
Boston Nectarine	9-H-1 to 9-I-1	White
Early-Red-Free	9-L-2 to 9-L-3	Creamy-white
Improved Pallas	9-H-1 to 9-I-1	White
Jewell	9-H-1	White
Korean	9-I-1 to 9-J-1	White
Laterose	9-L-1	Creamy-white
Mayflower	9-J-1 to 9-L-1	White to creamy-white
Quetta Nectarine	9-H-1	White
Raritan Rose	9-G-1 to 9-K-1	White
Redrose	9-I-1 to 9-K-1	White
Rosebud	9-I-1 to 9-L-2	Creamy-white
Rubired Nectarine	9-I-1	White
White Hale	9-J-1	White
World's Earliest	9-I-1 to 9-L-1	White to creamy-white

a few seedlings, of which the skin of the fruit was almost completely colored with dark red. There appeared to be an association between this red overcolor of the yellow leaves and the amount of red skin color of the fruit, but this relationship was not definitely established.

Varieties and seedlings differed in the time of the season at which leaves yellowed and abscissed. Hence, it was desirable to repeat the leaf sampling several times during the season from June until September.

DISCUSSION

The practical application of this yellow leaf "marker" character is twofold (1). When nurserymen bud yellow-fleshed varieties upon white-fleshed understock and the buds fail to "take", the resulting seedling trees may be detected by their pale yellow leaf color (2). Peach breeders may discard white-fleshed seedlings in the greenhouse bench upon the basis of their yellow leaf color, since withholding water from the plants tends to encourage dropping of these yellow leaves. With a little experience the observer may readily determine peach fruit flesh color at a glance by observing the shade of yellow color of the fallen leaf.

SUMMARY

The shades of yellow coloring of peach leaves, which drop during the summer, have been compared with the color of the fruit flesh when ripe. Matching leaf colors with color charts appearing in Maerz and Paul's "Dictionary of Color" determined that leaf colors ranging from 9-H-1 to 9-J-1 (pale yellow) were obtained from trees bearing white-

fleshed fruit; colors of 9–K–1, 9–L–1, and 9–L–2 generally indicated intermediate creamy-white fleshed fruit; and colors from 9–L–5 to 9–L–9 (deep yellow) were obtained with leaves from yellow-fleshed peaches. Tree vigor and position of the leaves upon the tree tended to affect slightly the shade of yellow coloring of the leaves.

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Ripeness and Color Studies with Raw and Canned Peaches[1]

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Ripeness and color are important factors of quality for peaches as well as other fruit. Until recently, there was no accurate objective method for obtaining color values. Color has been described in so many words (1, 4, 7) with the admission that a true color description is almost impossible (5) or reference has been made to standard color charts (2, 10), which was not entirely satisfactory. Working on the assumption that the quantity of green pigment in the flesh is an accurate physiological indication of ripeness, Kramer and Smith (3) proposed a method which is based on the spectrophotometric measurement of a pigment extract of the flesh of the fruit. A further simplification of this method is presented in this paper. An alternate method based on fluorometric measurements was found by Kramer and Smith to be affected by the carotinoids that are also present in the fruit. They, therefore, suggested that in the event that ripeness values as determined organoleptically may be found to be affected somewhat by the presence of the predominant yellow-orange pigments, the fluorometric method might reflect more closely consumer understanding of ripeness than the spectrophotometric method which provides an accurate measure of green pigment content only.

The bulk of the literature on storage of raw peaches is primarily concerned with increasing the storage life of the raw product, and consequently deals with low storage temperatures. Thus Allen (1) reports an improvement in the yellow color of peaches held in refrigerator cars for 10 days at temperatures of 43 and 52 degrees F. Veldhuis and Neubert (10) state that peaches stored at 31 to 45 degrees F may remain acceptable for periods up to 2 to 4 weeks, provided they are harvested within 5 days of canning ripeness. O'Reilly (8) reviews much of the literature concerning the low temperature storage of peaches, and concludes that a delay of 1 or 2 days at about 75 degrees F before cold storage eliminates loss of flavor after removal. He also reports better quality from the more mature fruit, and that modified atmospheres do not result in longer storage life. Overholser (9) states that ethylene does not improve the quality of immature peaches, but does hasten the ripening process.

Holding peaches for canning is more of a ripening process than a storage process. Neubert and Mottern (6) state that the correct time to harvest peaches is when the green color disappears, revealing a straw yellow color, and the fruit begins to soften. When picked at this stage, the fruit should be at optimum canning quality in 1 to 4 days at ordinary temperatures. If the fruit is allowed to remain on the tree until it is at the ideal soft ripe stage, it is subject to considerable bruising. Overholser (9) on the other hand, warns against picking fruit at

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a too immature stage because the green pigment does not entirely disappear and the yellow pigment will not fully develop.

Regarding the proper temperatures for ripening fruit for canning, Neubert and Veldhuis (7) found that fruit when ripened for the proper length of time at 65 degrees F resulted in a light yellow canned product, while fruit at a similar stage of maturity, held at higher temperatures, resulted in a canned product having a deeper yellow color.

Materials and Methods

Several trees of Elberta, Summercrest, and Halehaven peaches were selected for uniformity in a commercial orchard in Western Maryland. A wedge shaped portion of each tree was picked at the time that commercial picking of other trees in the same block began. Additional portions of the same trees were harvested several days later, when the commercial picking was completed, and the remainder of the peaches were picked for a third time when they were approaching the fully ripe stage. At all times the part of the tree selected for picking was harvested entirely irrespective of the stage of ripeness of individual fruits, so that random samples were representative for the variety as a whole at each picking time.

The peaches were then brought to the laboratory and held overnight. One portion of the lot was canned the following morning, and the remaining material was divided into three portions which were placed in 60 degrees F, common (75 to 80 degrees F), and 88 degrees F storages respectively. Samples from each storage were then canned 36, and 60 hours after harvest.

The processing steps consisted of halving, lye peeling, and trimming for major defects. The equivalent of one can of fruit was measured for its color components in the raw stage after preparation for processing, and the balance of the fruits were filled in No. 2 cans, with sirup of 50 degrees added, exhausted for 3 minutes, closed and processed in boiling water for 25 minutes. One can of each sample was measured for its color components 24 to 28 hours after processing. The remainder of the canned samples are being held in storage at different temperatures to be measured at later dates for their color components to determine the effect of different storage temperatures and periods on color changes that might occur after canning.

The methods used for evaluating ripeness and color have been described elsewhere (3). The spectrophotometric method for determining the green pigment concentration calls for repeated extraction of a 50-gram sample, concentration of the extract to a small volume, and clarification. An alternate procedure is now available based on the use of a 100 ml absorption cell in the Beckman spectrophotometer. This modification makes possible the use of a smaller sample, and eliminates entirely the need for concentrating the pigment. The alternate procedure is as follows:

Transfer 32 grams of blended pulp to a Waring Blendor cup with a small amount of water, add 150 ml ethyl ether and blend for 5 minutes. Transfer the contents of the blendor cup to a graduated cylinder,

and make up the ether layer to 150 ml. Decant about 45 ml of the ether solution into a centrifuge tube, centrifuge for about 10 minutes. Transfer the clear solution to a 100 mm absorption cell and measure at 665 mμ in a Beckman spectrophotometer, adjusted with pure ethyl ether as 100 per cent transmittance.

A series of tests has shown that results by the alternate procedure are for all practical purposes the same as those by the original procedure. The advantage of the above procedure is in its simplicity and rapidity.

Discussion of Results

The data in Tables I to IV summarize the results as obtained after the basic data were analyzed by the "analysis of variance" method. The analysis of the data for the Halehaven variety, presented in Table I, shows that there was a very large increase in ripeness as a result of every delay in date of harvest as measured both by the green spectrophotometric method, and by the fluorometric method. At the same time there was also a significant increase in the amount of yellow pigment. The data also indicate that there was considerable loss of green pigment during storage of the raw fruit, but the effect of the temperature of storage within the limits of 60 to 88 degrees F was of only minor importance. Both temperature and duration of storage had only small effect on the development of yellow pigment in the raw stored fruit. For Halehaven the canning process had no effect on the green pigment as measured spectrophotometrically, but did reduce the yellow pigment substantially, and consequently caused an apparent gain in green pigment as measured fluorometrically.

TABLE I—Effect of Date of Harvest, Duration and Temperature of Storage of the Raw Fruit on the Ripeness and Color Values of Raw and Canned Halehaven Peaches

Effect of	Green Pigment		Yellow Pigment
	Spectrophotometer* at 665 mu	Fluorometer**	Spectrophotometer† at 450 mu
Date of Harvest:			
Aug 13	49.6	247	67.4
Aug 18	72.7	95	57.6
Aug 21	79.6	38	56.4
Duration of Storage:			
12 hours	60.0	178	62.8
36 hours	66.7	130	61.4
60 hours	75.1	100	57.2
Temperature of Storage:			
60 degrees F	65.3	145	62.6
Room‡	67.3	135	60.4
88 degrees F	69.2	128	58.6
Processing:			
Raw	67.6	126	55.4
Canned	66.9	146	65.6
Difference required for significance: 5 per cent	2.4	8.2	1.5
Difference required for significance: 1 per cent	3.6	12.3	2.2

*Beckman spectrophotometer, using 10 mm cell, and approximately .03 slit opening.
**Klett fluorimeter, standardized with quinine sulfate, 10 ppm =35.
†Beckman spectrophotometer, using 10 mm cell, and approximately .15 slit opening.
‡Approximately 78 degrees F.

The Summercrest variety (Table II) was harvested at only one

date so that no data are available for date of harvest comparisons. Furthermore, because of the limited numbers of samples, no significance can be attached to the effect of storage temperature of canning on changes in color. The duration of storage, however, had a significant effect on the reduction of the green pigment and the gain in yellow pigment.

The analysis of the data for the Elberta variety is presented in Table III. The results are similar to those obtained for Halehaven, with the following exceptions. There appears to be a significant increase in the green pigment as a result of processing. This is probably

TABLE II—Effect of Duration and Temperature of Storage of the Raw Fruit on the Ripeness and Color Values of Raw and Canned Summercrest Peaches

Effect of		Green Pigment: Spectrophotometer* at 665 mu	Green Pigment: Fluorometer**	Yellow Pigment: Spectrophotometer† at 450 mu
Duration of Storage:				
12 hours		42.0	300 +	69.0
36 hours		47.7	300	76.0
60 hours		60.0	194	67.0
Temperature of Storage:				
60 degrees F		49.3	300 +	72.5
Room‡		49.8	300	70.8
88 degrees F		50.5	292	69.0
Processing:				
Raw		51.4	273	69.0
Canned		48.7	300 +	72.6
Difference required for significance	5 per cent	4.7	14	4.0
	1 per cent	7.0	25	6.0

*Beckman spectrophotometer, using 10 mm cell, approximately .03 slit opening.
**Klett fluorimeter, standardized with quinine sulfate, 10 ppm = 35.
†Beckman spectrophotometer, using 10 mm cell, and approxiamtely .15 slit opening.
‡Approximately 78 degrees F.

TABLE III—Effect of Date of Harvest, and Duration and Temperature of Storage of the Raw Fruit on the Ripeness and Color Values of Raw and Canned Elberta Peaches

Effect of		Green Pigment: Spectrophotometer* at 665 mu	Green Pigment: Fluorometer**	Yellow Pigment: Spectrophotometer† at 450 mu
Date of Harvest:				
Sep 2		45.2	300 +	74.7
Sep 6		65.1	162	66.6
Sep 9		73.3	87	62.4
Duration of Storage:				
12 hours		50.3	274	67.2
36 hours		62.2	165	68.3
60 hours		71.0	118	68.2
Temperature of Storage:				
60 degrees F		58.9	193	69.4
Room‡		61.7	187	68.9
88 degrees F		62.9	173	65.4
Processing:				
Raw		62.4	165	65.4
Canned		59.9	204	70.4
Difference required for significance	5 per cent	0.8	14	1.4
	1 per cent	1.8	26	2.2

*Beckman spectrophotometer, using 10 mm cell, and approximately .03 slit opening.
**Klett fluorimeter, standardized with quinine sulfate, 10 ppm = 35.
†Beckman spectrophotometer, using 10 mm cell, and approximately .15 slit opening.
‡Approximately 78 degrees F.

due to the fact that all of the raw fruit was measured as it was, while the analysis of the canned fruit was made on the drained portion only. Since neither the green nor the yellow pigments are water soluble, their concentration would appear to be higher after draining because of the partial loss of water and water soluble components. The loss of the yellow pigment as a result of canning, though highly significant, did not appear to be as considerable as the loss of yellow pigment for the Halehaven variety.

The apparent lack of effect of duration of storage on the yellow pigment is explained by a significant interaction of time and temperature of storage (Table IV), indicating that for Halehaven peaches there was no change in yellow pigment as a result of storage at 60 degrees F and an increase at the higher temperatures, while for the Elberta peaches, there was actually a loss of yellow pigment at low temperature storage, but a significant gain in pigment at the high storage.

TABLE IV—Effect of Interaction of Time and Temperature of Storage on the Development of the Yellow Pigment in Raw and Canned Peaches

Variety	Duration of Storage (Hours)	Temperature of Storage Per Cent Transmittance, 450 mu		
		60 Degrees F	Room*	88 Degrees F
Hale Haven	12	62.8	62.8	62.8
	36	62.8	62.5	59.0
	60	62.0	55.8	53.8
Elberta	12	67.2	67.2	67.2
	36	69.0	70.1	65.8
	60	72.0	69.5	63.2

Difference required for significance:
5 per cent—2.5
1 per cent—3.8
*Room temperatures averaged 78 degrees F (range 74 to 81 degrees F).

These findings are in agreement with the observations of Neubert and Veldhuis (7) to the effect that peaches held at high temperature storage before canning resulted in a better colored product than similar peaches held at 65 degrees F. On the other hand, Allen's (1) observations of improvement in the yellow color of peaches held at 43 and 52 degrees F, may have been the result of the disappearance of a masking green pigment rather than an actual increase in the concentration of yellow pigment.

Summary and Conclusions

These data tend to validate from a physiological standpoint the assumption that a loss in green pigment is an indication of ripening of peaches, since every delay in harvest caused a substantial reduction in green pigment concentration, as measured by the spectrophotometric and the fluorometric methods. The data also indicate that within the limits of 60 to 88 degrees F the duration of storage of the raw fruit is more important in ripening than is the temperature of storage, except that the fruit tends to "color up" (more yellow pigment) better at higher storage temperatures. The data further substantiate the fact

that the green pigment is the more stable, since it was affected almost not at all, while the yellow pigment was decreased considerably as a result of the canning process. The greater apparent increase in green pigment as a result of processing as measured fluorometrically, may be partly ascribed to the loss of yellow pigments which mask the fluorescence of the green pigment.

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Size in Canning Peaches. The Relation Between the Diameter of Cling Peaches Early in the Season and at Harvest

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CANNING peaches in California are grown under what could well be considered reasonably uniform conditions. A large part of the acreage is concentrated in two areas; the entire tonnage is grown with irrigation whereby the trees rarely suffer for water; the set is heavy enough that thinning is required each year; the fruit is allowed to reach full size and maturity before it is picked. In spite of what seems to be fairly uniform conditions there have been rather large variations in the average size of the fruits from year to year. Observations had suggested that there was a relation between the size of fruit at harvest and that at periods early in the season. In those seasons when the average size at harvest was large, the size at thinning time or somewhat earlier seemed to be large and the seasons of small sizes at harvest were the seasons when the fruit at the earlier period was relatively small.

This paper reports certain of the data which have been obtained as a part of the study of the size relations in canning clingstone peaches.

MATERIALS AND METHODS

In this investigation the suture diameter was selected as the best indicator of size. The size of delivered canning peaches is determined by the largest diameter perpendicular to the axis of the fruit. In a majority of cases this is the suture diameter and this is particularly the case as the minimum size for delivery (2⅛ inches) is approached.

The period chosen for the date of the first measurement was 10 days after the extreme tip of the pit had begun to change in color from white to a creamy yellow and had hardened enough that the blade of a sharp knife would hesitate when successive thin sections were cut through the distal end of the fruit. A number of reasons determined this choice. (a) The change in color and degree of hardness of the extreme distal end of the tip can be determined accurately and easily in the orchard by anyone. (b) Ten days after this change in color of the tip marks the beginning of the second growth period of all our canning varieties. It is important that the date of the first measurement be during a period of minimum growth so that the variations which inevitably occur in its selection will result in the minimum change in size of the fruits. (c) The date is at the beginning of our normal thinning season. Consequently any information obtained relative to the size of the fruit at this time and at harvest might be used in the thinning program. The position of these two dates on the growth curve of the Paloro variety is shown in Fig. 1. The date when the change in the tip has been observed has been designated as "tip change" and the second date 10 days later as "reference date". These terms will be used in the remainder of this paper.

Small numbered metal-rim tags were placed on individual fruits and

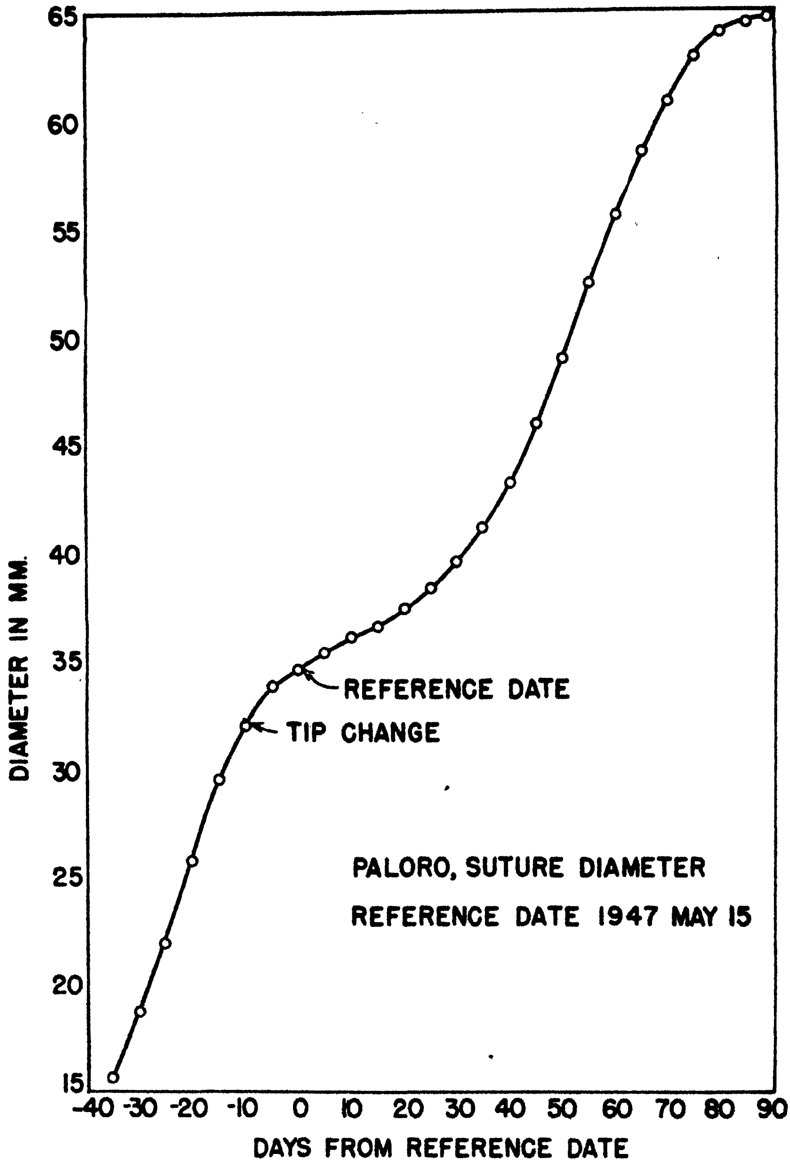

Fig. 1. Growth curve of Paloro peach.

their suture diameter measured to 0.1 mm with a vernier caliper at or soon after the reference date. The largest deviation from the reference date for this first measurement has been 3 days. These fruits were measured again at harvest. The tags were always placed in groups or units of 25. All fruits on a branch that were in a position to be measured

and were expected to remain until harvest were tagged. Each group was kept as compact as possible; the fruits of a unit were not scattered up and down the tree. Thus, one ladder set might account for one or as many as three groups. Thinning was done by the grower near the reference date; the thinning was the same as that used on the remainder of the block.

The data have been obtained from two general sources. In one case data obtained in the preparation of growth curves have been utilized. The curves have been obtained for certain varieties over a period of years in the manner usually employed by investigators in which tagged fruits are measured at approximately weekly intervals throughout the growing season. For the Phillips Cling these data have been obtained for most of the years beginning with 1930. In the other case 250 to 500 fruits on one tree have been tagged and measured at reference date and at harvest. Data from this source have been obtained from 1940 through 1947 for a number of varieties.

Results

The relation between the size at reference date and at harvest, as reflected by the suture diameter, has been examined by computing the coefficient of correlation *r*. Certain groupings or combinations have been made in order more fully to explore the relations involved. (a) The correlation has been determined for individual fruits on one tree for each season for a variety. (b) It has also been calculated for the mean size of the groups of 25 fruits for one tree in one season, by combining all the trees of a variety for one season, and by combining all trees of a variety for all the seasons. (c) The correlation has been computed when the mean size for all the tagged fruits on a tree was used and all the trees of a variety for all the seasons were considered.

Table I presents representative data for eight consecutive seasons chosen from more than 125 correlations for the period 1940 to 1947 inclusive, for the relation between the diameter at reference date and that at harvest for the Paloro, the Gaume and the Phillips Cling. The Paloro is one of the earlier ripening varieties of our canning clingstones, the Gaume, a mid-season one and the Phillips Cling one of the latest maturing. The computations have been made for individual fruits

TABLE I—Coefficient of Correlation *r* Between the Suture Diameter at Reference Date and at Harvest for Individual Fruits and for Their Means When Grouped in Units of 25, from Single Trees

Year	Individual Fruits Variety			Means of Units of 25 Fruits Variety		
	Paloro	Gaume	Phillips Cling	Paloro	Gaume	Phillips Cling
1940	0.769	0.609	0.753	0.887	0.748	0.936
1941	0.731	0.726	0.827	0.919	0.714	0.937
1942	0.658	0.620	0.667	0.186*	0.863	0.676
1943	0.590	0.649	0.617	0.815	0.792	0.690
1944	0.817	0.526	0.607	0.916	0.841	0.702
1945	0.513	0.551	0.631	0.739	0.660†	0.896
1946	0.462	0.605	0.755	0.343*	0.709	0.955
1947	0.625	0.686	0.732	0.898	0.935	0.874

*Not significant.
†Significant at the 5 but not at the 1 per cent level.

on single trees and for the means of the groups of 25 for these same fruits. The correlations shown are all highly significant for the inividual fruits on single trees. This has been the situation for all cases of this kind; all have had values of *r* that were hightly significant.

There are two cases of the correlations for the units of 25 fruits that are not significant and two that are significant at the 5 per cent but not at the 1 per cent level. All the correlations indicate the same relation for the units of 25 fruits on single trees; a few have not been significant, a few have been significant at the 5 per cent level; but the large majority have been highly significant. Since these data seem to indicate location influences, in this study mean values for units may be used equally as well as measurements on individual fruits.

Table II presents representative data using means of the units of 25 fruits, for the correlation between the size at reference date and at harvest for all the trees of a variety studied in one season. This represents a combination of data from trees growing in different orchards but in the same season. The value of *r* is highly significant in all cases and is in agreement with all the data obtained when the additional variable of location has been introduced.

TABLE II—Coefficient of Correlation *r* Between the Suture Diameter at Reference Date and at Harvest for All Trees of One Variety in a Season When the Means of Units of 25 Fruits Are Used

Variety	Season	r	Variety	Season	r
Paloro	1940	0.701	Gaume	1942	0.813
Paloro	1941	0.803	Gaume	1943	0.680
Paloro	1942	0.713	Gaume	1944	0.580
Paloro	1947	0.783	Gaume	1947	0.982
Halford	1941	0.805	Phillips Cling	1930	0.932
Halford	1945	0.522			

Table III presents the values of *r* when, for a variety, the data from all trees and all seasons were combined. This procedure adds the possible variable of the effect of season to the data in Table II. Computations have been made using the means of the unit of 25 fruits and on the tree-unit basis. In the latter case the mean of all the tagged fruit on a tree has been used as the variable on the assumption that this figure would represent the performance of the tree as a whole with respect to its

TABLE III—Coefficient of Correlation *r* Between the Suture Diameter at Reference Date and at Harvest for All Trees and All Seasons When the Means of Units of 25 Fruits and the Means of All Tagged Fruits on a Tree Are Used

Variety	Seasons	r Using Means of Units of 25 Fruits	Variety	Seasons	r Using Means of Tagged Fruits on One Tree
Paloro	1940–1947 inc.	0.734	Paloro	1940–1947 inc.	0.760
Peak	1941–1945 inc.	0.619	Peak	1941–1945 inc.	0.705
Johnson	1942–1946 inc.	0.687	Johnson	1942–1946 inc.	0.698
Gaume	1940–1947 inc.	0.740	Gaume	1940–1947 inc.	0.775
Sims	1941–1943 inc.	0.599	Halford	1941–1947 inc.	0.829
Halford	1941–1947 inc.	0.825	Phillips Cling	1940–1947 inc.	0.760
Phillips Cling	1940–1947 inc.	0.806			

sizing ability. All the values of r are highly significant either on the basis of the means of 25 fruits or of the means of all the tagged fruits on a tree.

Discussion

The conditions under which these data have been obtained should be kept clearly in mind. The trees have been located in the two major canning peach growing areas, the orchards have been well cared for but have not been selected as the best; all have been irrigated and probably have never suffered for water during the growing season; the thinning has been done by the grower and in conformance with his practice. The latter situation might be expected to introduce variations in response since there have no doubt been differences in opinion among the growers with respect to the need and type of thinning required by their orchards. Such variations might be expected to lower the values of r especially when the data for trees from different locations and different seasons are combined.

The values of r are highly significant irrespective of the method of treatment of the data. When individual fruits on a single tree are considered perhaps the minimum number of variables is involved; they are confined to single units of an organism. When the means of units of 25 fruits on one tree are used an additional factor may be introduced. The means could very well hide any differences in sizing ability of the individual fruits and the values of r would be lowered when compared to those for single fruits. The fact that the values of r for the units of 25 fruits on a single tree are nearly all highly significant may be taken as evidence that the fruits in each unit have uniform sizing abilities.

When the data for all the trees of a variety investigated for one season were combined, an additional factor capable of causing variation, that of the sizing ability of trees caused by such things as different ages, varying cultural treatments and geographical locations was included. This method of treatment has not lowered the significance of the correlations.

The combination of data of a variety for all trees and all seasons investigated has introduced another factor capable of causing variation, that of the effect of different seasons. Here again the values of r are all highly significant.

A number of factors may be responsible for the correlations reported here. Common elements undoubtedly play an important part; two examples will be indicated. (a) It could be assumed that the diameter of the fruit at reference date was an expression of the integration of all those factors which go to make up size. It might further be assumed that the sizing ability as expressed by the size at reference date was an element common to the whole season and would therefore be operative in the increment of growth made after that date. Size at reference and size at harvest, as expressions of this common element of sizing ability, would therefore be correlated. (b) The harvest diameter consists of the diameter at reference date plus the increment of growth made after that time. The size at reference would thus constitute a part of the harvest size and consequently a common element contributing to the value of r. The average size of the Paloro at reference date for all sea-

sons was 53 per cent of the harvest size, for Gaume 52 per cent and for Phillips Cling 54 per cent. It will be shown in a subsequent paper that the correlations between the increment of diameter growth from reference date to harvest are usually much larger than that between the size at reference date and at harvest.

Aside from the possible causes of the correlations certain implications are indicated.

The value of r may be taken as a measure of the scatter around the regression line and hence a measure of the success of estimating the value of one variable from that of the other (1). From regression equations the size at harvest could be estimated from the size at reference date. The grower could then have an objective measure of his thinning problem from the size at reference date and could adjust his thinning operations in an effort to influence the harvest size in the desired direction from the estimated one.

The use of regression equations could be extended to periods later in the season than the reference date when the grower could evaluate again the size of his fruit in relation to the job of thinning that had been done and the estimated size at harvest and make any further adjustments that were feasible.

The industry as a whole frequently needs an estimate of the harvest sizes well in advance of maturity. The techniques indicated here may well be used for this purpose.

It would seem that the values of r for the correlations between harvest size and increments of growth for various intervals of time could well be used as a measure of the relative importance of these intervals in the investigation of the general problem of size in peaches.

Summary

The coefficients of correlation r between the suture diameters of canning peaches early in the season at a period called reference date and at harvest are highly significant whether they are for fruits on one tree in one season, for fruits on a number of trees in one season or for fruits on a number of trees for a number of seasons.

It is suggested that the regression equations for the relation between the diameter at reference date and at harvest can be used to make an estimate of the expected harvest size whereby the grower can adjust his thinning operations in an effort to cause his harvest size to deviate from the estimated one in the desired direction.

It is also suggested that regression equations to express the relation between diameters at periods later in the season than the reference date and at harvest might be used by the grower to reevaluate his sizing problem and by the industry to prepare an estimate of the expected sizes at harvest.

It seems that the use of correlations would be a useful tool in studying the relative importance of increments of growth during various intervals of time.

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Prolonging Shelf Life of Plums with Carbon Dioxide[1]

By VLADIMIR SHUTAK and E. P. CHRISTOPHER, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

PLUMS and other stone fruits ripen very rapidly at room temperature. Sizeable losses occur in retail outlets due to overripeness and the development of certain diseases especially brown rot. Treatments to prolong "shelf life" would benefit both the retailer and consumer.

Carbon dioxide has been used with considerable success in retarding ripening and checking the development of disease during transit (1, 2, 4, 5). English and Gerhardt (5), working with brown rot control on sweet cherries, found that carbon dioxide would reduce significantly the incidence of the disease at high temperature but its effectiveness decreased to the vanishing point at 31 degrees F.

Allen (1) working with cherries, plums, peaches, and pears, used carbon dioxide concentrations up to 60 per cent in treatments of 2 to 10 days and reported increased storage life. He found that the reduction in oxygen concentration retarded coloring and softening.

Brooks *et al* (2) working on several fruits and vegetables at different temperatures and with various carbon dioxide concentrations, pointed out certain dangers in the use of carbon dioxide. High concentrations may cause loss of aroma and prolonged treatments may result in fermentation and loss of flavor. In general, increasing concentrations above 25 per cent did not greatly shorten the period of safe treatment. The effect upon flavor was more pronounced at high temperature; thus, temperature was often the determining factor in establishing the duration of treatment. Carbon dioxide not only decreased the development of rots, but was even more beneficial in checking the softening and ripening rate of the fruit. Other benefits were also reported, such as reduced shattering of grapes and the retaining of sugar in sweet corn, peaches and carrots.

Claypool and Allen (4) reported results with Santa Rosa plums exposed to various concentrations of CO_2 and O_2. Differential treatments were of 10 days' duration and all lots were ripened at 65 degrees. Treatments at 40 degrees were less effective than those at 65 degrees. In the CO_2 series, concentrations of 25 to 60 per cent were most effective in retarding ripening and decreasing rots, but fruits exposed to concentrations of 40 per cent and above failed to ripen.

Preliminary work at Rhode Island (3) was carried on with Stanley plums provided by the University of Connecticut. It was found that plums absorb great quantities of CO_2 when exposed to high concentrations, but lose it without injury when they are returned to normal atmospheres. Plums placed in cellophane bags immediately following treatment were held 4 to 5 days at room temperature without harmful results. Ripening was delayed and brown rot was less severe. Scott

[1]Contribution No. 718 of the Rhode Island Agricultural Experiment Station, Kingston, Rhode Island.

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and Tewfik (6) have reported differences in the permeability of various cellophanes and other films to CO_2. More work should be done before this treatment can be recommended.

Procedure

This experiment was designed to investigate the feasibility of using CO_2 when a retailer has to hold fruit for a few days without refrigeration. With this point in mind a container was selected which was not air tight, thus eliminating any necessity for special equipment. For the same reason no effort was made to maintain CO_2 concentrations at a constant level throughout the treatment.

A cardboard barrel with a volume of about 5 cubic feet and a tight cover was used as a treatment chamber. For each run, 1000 grams of dry ice were placed in the bottom of the barrel and allowed to sublimate gradually. The CO_2 concentration was checked at intervals, increased to 70 per cent in 1 hour and 85 per cent at the end of 6 hours, then decreased until at the end of the 15-hour run it was usually 65 to 75 per cent.

Santa Rosa, Burbank, Reine Claude and Grande Duke plums used in this experiment were grown in the college orchard at Kingston, Rhode Island. Fruit was harvested ripe, ready for the retail trade. The plums were packed in 4-quart grape-baskets (about 50 fruits each) and placed on a rack in the bottom of the barrel. Check fruit was put in a similar basket and kept near the barrel at all times.

Treatments consisted of subjecting similar lots of fruits to high CO_2 concentrations for 15 out of every 24 hours. Treatments started at 5 p m and were terminated at 8 a m the next morning. Some lots of fruit received repeated treatments on consecutive days and are designated as CO_2 x 1, CO_2 x 2, CO_2 x 3, CO_2 x 4, or CO_2 x 5 to indicate the number of days involved.

Thermocouples were used to determine fruit and air temperature both inside and outside the barrel. Variations did not exceed 3 degrees F between the check and treated fruit. Frequently in spite of the dry ice, temperature in the barrel was higher than that outside. This was especially true in the early evening when the outside air began to cool.

In some of the lots 10 to 25 fruits were inoculated with brown rot. A circular piece of skin $^1/_{16}$ inch in diameter was removed and brown rot spores from scrapings were placed on the exposed flesh of the fruit. When records were taken to determine spread of rot, average diameter of affected tissue was measured.

Pressure tests were taken with a Magness pressure tester fitted with a $^7/_{16}$-inch tip.

Results

Burbank plums were picked on August 23, stored at 32 degrees, and treatments were started August 25. The average temperature during the treatments was 75 degrees from 8 a m to 8 p m and 72 degrees from 8 p m to 8 a m. The last treatment ended August 28 and records were taken at 7 p m August 29.

Pressure tests (Table I) indicate that ripening was definitely re-

TABLE I—PRESSURE TESTS OF BURBANK PLUMS AS AFFECTED BY CO_2 TREATMENTS (AUGUST 1947 — RECORD TAKEN 6 DAYS AFTER HARVEST)

Treatment	Mean Pressure (Lbs)	Remarks
Check	7.5	Unmarketable—overripe
$CO_2 \times 1$	7.8	Marketable—ripe
$CO_2 \times 2$	10.8	Marketable—firm ripe
$CO_2 \times 3$	14.2	Marketable—firm ripe
$CO_2 \times 4$	23.9	Marketable—firm ripe, slightly tart

tarded. There were no other effects from CO_2 except a slight tartness in the lot which received four treatments on four consecutive days.

Statistically the CO_2 x 4 treatment was significantly better than any other; CO_2 x 3 was better than the check and CO_2 x 1; and CO_2 x 2 was better than CO_2 x 1 or check. (Significance was considered only at 99:1 odds).

Reine Claude plums were picked on October 14, stored at 40 degrees F overnight, and the treatment was started the next day. Results (Table II) show that most of the fruit was unmarketable, but this is because fruit was picked fully ripe and because records were not taken until two complete days after the last treatment.

TABLE II—PRESSURE TESTS OF REINE CLAUDE PLUMS AS AFFECTED BY CO_2 TREATMENTS (OCTOBER 1947 — RECORD TAKEN 7 DAYS AFTER HARVEST)

Treatment	Mean Pressure (Lbs)	Remarks
Check	7.0	Unmarketable
$CO_2 \times 1$	8.2	Unmarketable
$CO_2 \times 2$	9.0	Unmarketable
$CO_2 \times 3$	10.3	Marketable (if picked over)
$CO_2 \times 4$	10.6	Marketable

Least difference required for significance at 19:1 odds = 1.39; at 99:1 odds = 1.83

Reine Claude plums were pressure tested before the first treatment and the average pressure was only 11.5 pounds. Therefore a pressure of 10.6 pounds after 6 days at room temperature is considered good. Average temperatures during treatments were 72 degrees during the day and 70 degrees during the night.

Only a small sample of Santa Rosa plums was available. It was divided into two lots: check and CO_2 x 4. After 5 days the average pressure of the check was 19 pounds, and 24 pounds for CO_2 x 4; checks were fully ripe while treated fruit was firm ripe with a slightly bitter taste.

TABLE III—PRESSURE TEST OF GRANDE DUKE PLUM AS AFFECTED BY CO_2 TREATMENTS (OCTOBER 1947 — RECORD TAKEN 6 DAYS AFTER HARVEST)

Treatment	Mean Pressure (Lbs)	Remarks
Check	4.6	Unmarketable
$CO_2 \times 1$	6.0	Unmarketable
$CO_2 \times 2$	6.0	Unmarketable
$CO_2 \times 3$	8.0	Marketable
$CO_2 \times 5$	11.5	Marketable

Grande Duke plums were picked October 2 and treatments started on October 3. The average pressure before treatments was 16.0 pounds. Analysis of data presented in Table III show that CO_2 x 5 was significantly better than any other treatment; CO_2 x 3 was better than check, CO_2 x 1, and CO_2 x 2; other treatments did not show significant differences at odds of 99: 1.

Data on brown rot inoculations are presented in Table IV. Results were better with Reine Cluade than with Burbank but both show the benefit of CO_2 treatments.

TABLE IV—Development of Brown Rot Inoculation as Affected by CO_2 Treatments

Treatment	Mean Diameter of Affected Tissue (Inches)	
	Burbank Plum	Reine Claude Plum
Check	3.38	1.91
$CO_2 \times 1$	2.88	1.00
$CO_2 \times 2$	2.38	0.70
$CO_2 \times 3$	1.50	0.66
$CO_2 \times 4$	1.00	0.38

Least difference required for significance for Burbank plum at 99:1 odds =.763. Least difference required for significance for Reine Claude plum at 99:1 odds =.614.

Conclusions

Shelf life of plums can be prolonged without the use of refrigeration. Subjecting plums to a high concentration of CO_2 for 15 out of every 24 hours for five consecutive days retarded ripening and decreased the spread of brown rot. No bad effects or serious off-flavor were found in any of the lots; in many instances tasters actually preferred the flavor of a treated plum.

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Sizes of Prunes as Influenced by Differences in Set and Irrigation Treatment

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THE rainless summers in California present an opportunity to study the relations between controlled soil-moisture and size of fruit. Prunes are an excellent subject for studies on this problem, because they continue growth until comparatively late in the season and, as a rule, are not thinned. The entire crop, furthermore, is harvested, and it is an easy matter to secure the size grades of all the fruits, including those ordinarily classed as culls. Results of studies relating to the effect of irrigation on size of fruit are sometimes obscured by thinning, and by the failure to record the weights and numbers of the culls, thus placing undue emphasis on the amount of marketable fruit produced.

In 1947 a prune orchard at Davis, California, devoted to irrigation experiments, presented an excellent opportunity to study the effect of irrigation, or the lack of it, on the sizes produced. Considerable variation in the natural set of fruit occurred among the replications of the different treatments. Thus, some plots in the irrigated treatments produced moderate crops while others produced light ones. Approximately similar variations occurred in the unirrigated treatments. In no case was the set of fruit so great that average sizes were reduced by numbers alone, as is sometimes the case with heavy crops.

The trees are growing in a Yolo loam having a field capacity and a permanent wilting percentage of about 22 and 11 per cent, respectively. The trees are 24 feet apart on the square system, and were 24 years old when the records were secured. The unirrigated plots, seven in number, received no water while the crop was on the trees, and the readily available moisture, from the winter rains, was exhausted to a depth of 6 feet about the middle of July. Three of the irrigated plots received four irrigations each with a total of about 24 acre inches per acre before the crop was harvested. The soil-moisture contents in these plots did not go below 13 or 14 per cent in the top 6 feet during the growing season. The fourth irrigated plot (plot number 5) was watered 10 times during the season with a total of 96 acre inches per acre. This plot was irrigated so frequently that the soil was saturated for a considerable portion of the season. Irrigation of this plot ceased about 2 weeks before harvest to permit the soil to become dry enough for the harvesting operations. The crop was harvested during the third week in August.

After picking, the prunes were dehydrated in the usual manner and run over a size grader. The dried fruit was separated into seven sizes, from which the weights and numbers of each size were obtained. The term "large prunes" as used in this paper refers to the fruits in the three largest size grades.

From the results given in Table I, it will be seen that the average number of prunes per tree showed considerable variation, but the magnitude of variation was about the same in both treatments. The largest

TABLE I—YIELDS AND SIZES OF FRENCH PRUNES IN 1947

Plot	Average No. Prunes (Per Sq Cm Trunk Cross-Section)	Average Fresh Weight Yields (Lbs Per Sq Cm Trunk Cross-Section)	Average No. Prunes Per Tree	Average Fresh Weight Yields (Lbs Per Tree)	Percentage of Large Sizes
			Irrigated		
5	45	0.323	3,737	188.1	69.3
17	81	0.424	6,185	257.1	29.5
29	74	0.386	5,490	228.9	47.6
56	14	0.090	967	49.8	88.4
			Unirrigated		
14	69	0.259	4,508	136.3	5.8
41	28	0.081	1,730	39.9	2.9
50	48	0.141	3,051	72.4	2.9
8	82	0.309	5,745	152.0	9.5
23	118	0.420	7,535	214.0	7.2
32	90	0.289	6,001	154.3	4.6
44	104	0.301	6,601	152.3	3.1

average number of fruits in the irrigated plots was slightly over 6,000, that in the unirrigated about 7,500 fruits with several plots about 6,000 fruits each. The lowest set in the irrigated plot was 967 fruits per tree, and in the unirrigated, 1,730. The average number of fruits in the irrigated plots was about 4,000 per tree while in the unirrigated, it was about 5,000. Thus, the unirrigated trees averaged a larger number of fruits than the irrigated. Inasmuch as the unirrigated trees were smaller than the irrigated ones, the number of fruits per square centimeter of trunk cross-section area was computed. The number of fruits per square centimeter, of trunk cross-section area in the irrigated plots varied from 14 to 81 with an average of 54, while the unirrigated ones varied from 28 to 118 with an average of 77. The difference, however, between these averages is not significant. In neither case was the set disproportionately heavy for the leaf area involved (assuming the trunk cross-section area to indicate size of tree and, hence, leaf area).

Although the unirrigated trees had a larger average number of prunes than the irrigated ones, the final results showed that the yields in pounds of the former were slightly less than those of the latter. The irrigated trees also had a slightly greater average yield per square centimeter of trunk cross-section area than the unirrigated ones. These differences are not statistically significant (by odds of 30 to 1). The data on yields of all sizes are included, not to indicate the merits of irrigation so far as total yields are concerned, as these results are best studied over a long period of time, but to show the relationship between irrigation treatment and the production of large sizes under conditions where there is a considerable variation in the set of fruit.

Previous results with prunes and other fruits have shown that fruit on trees supplied with readily available moisture continue to grow at the usual rate until attaining full size, while fruit on trees that have exhausted the available supply of moisture decrease in rate of growth. The percentages of large sized and most valuable prunes are given in the last column. The data show that the trees in the irrigated plots produced a considerable proportion a large sized fruit, while the un-

irrigated ones produced only a small percentage. In fact, in no case did the unirrigated trees produce more than 9.5 per cent of large sizes.

The results showing the relation between numbers of fruits per tree and percentage of large prunes are shown graphically in Fig. 1. The results from the unirrigated trees, indicated by crosses on the chart,

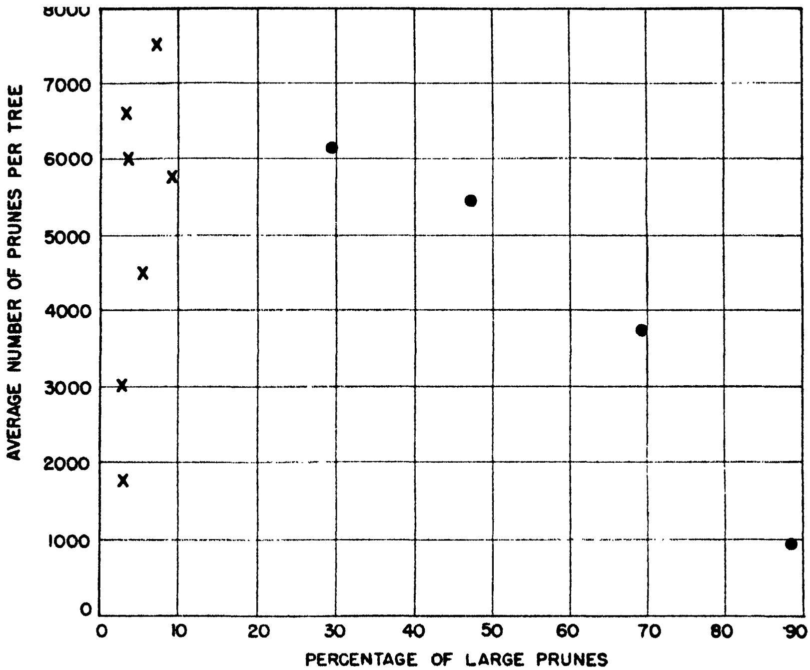

FIG. 1. Relationships between numbers of prunes and percentages of large sizes. The dots represent the irrigated plots; the crosses, the unirrigated.

show that in no case was there more than 9.5 per cent of large sizes even from the trees bearing very light crops. The lack of readily available moisture before the fruit reached full size, overshadowed any benefit as far as size is concerned that might have been expected from a light set. On the other hand, the percentage of large sizes from the irrigated trees bears almost a linear relationship to the number of fruits per tree. It is interesting to note that plot 5 which had 3,737 fruits per tree produced 69.3 per cent of the large sizes. These results are in keeping with the results from the other irrigated plots even though plot 5 received about four times as much water as the others. Apparently, the percentage of large sized prunes was not increased by the use of excessively large amounts of water.

Discussion and Summary

When soil moisture is readily available throughout the growing season and crops are light to moderate, the percentage of large sized

prunes is related to the total number of fruits per tree. In a previous report (1), the *weights* of the large sized prunes seemed to reach a maximum that was not closely related to the number of fruits. However, when plotted as a percentage of large sized fruits, the results were similar to those of 1947. On the other hand, when the readily available soil-moisture is exhausted before the fruits reach full size, prune trees, even those with light crops, produced a relatively small proportion of large fruit.

Maintaining soil moisture high in the available range, or, in other words, far above the permanent wilting percentage did not produce a larger percentage of large fruits relative to the total number than did normally irrigated trees.

In any one season for a given number of fruits per tree, when the crop is light to moderate, there seems to be a percentage of large fruits that may be expected. This percentage is not increased by the use of unnecessarily large amounts of water, but may be markedly decreased if the readily available moisture is allowed to become exhausted before the fruits are fully grown.

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Influence of the Rootstock on Injury from Excess Boron in French (Agen) Prune and President Plum

By CARL J. HANSEN, *University of California, Davis, Calif.*

IN 1935 Eaton and Blair (1), working with reciprocally grafted sunflowers and Jerusalem artichokes in one series of experiments, and with lemons and Chinese box oranges in another, found that boron accumulations in the leaves of the scion were influenced by the rootstocks upon which they were grown. As a result of this work, an experiment started in the spring of 1941 to determine the relative tolerance of fruit plants to excess boron was expanded to include President plum on myrobalan plum, apricot, and peach (Shalil) roots. The trees on peach and myrobalan plum roots were 1 year old and were headed about 1 foot from the surface of the soil at planting time. Those on apricot roots were root-grafted at planting time. The trees were grown in a Yolo-loam soil in cans (9½ inches in diameter and 11 inches deep), and were irrigated with water containing the following amounts of boron: Tap water (.5 parts per million), 2 parts per million, 3 parts per million, 5 parts per million and 10 parts per million. The trees were placed in the cans in the spring of 1941 shortly before they started to grow, and were watered with tap water until the differential treatments were begun on June 17, 1941.

Excess boron injury on European plum varieties such as the President plum and French prune may be easily identified (Figs. 1 and 3B). The tips of the shoots die back, and the bark becomes cracked and corky especially in the axils of the leaves. Sometimes gum may exude from the injured parts. Corky areas may also be found on the leaf petioles and on the large veins on the dorsal side of the leaves. If other conditions are normal for growth, the lateral buds on injured shoots will start to grow, only to be killed back later. By the end of the growing season many of the nodes will be considerably enlarged.

Observations made on October 16, 1942, and recorded in Table I show that the President plum trees on myrobalan plum roots were in considerably better condition than those on peach roots. The condition of the trees on apricot roots was intermediate.

TABLE I—CONDITION OF PRESIDENT PLUM TREES ON THREE ROOTSTOCKS (OCTOBER 16, 1942)

Irrigation Water	Rootstocks		
	Myrobalan Plum	Apricot	Peach
Tap water (0.5 ppm boron)	Normal	Normal	Normal
2 ppm boron	Normal	No tree available	Severe injury to stems; some injury to petioles
3 ppm boron	Normal	Very slight injury to 50 per cent of the stems	Very severe injury to stems; some injury to petioles; one of three main branches dead
5 ppm boron	Considerable injury to nearly all stems; one stem tip dead	Considerable injury to nearly all stems; corky areas on a few petioles; a few stem tips dead	Dead
10 ppm	Dead except for two myrobalan suckers	Dead	Dead

FIG. 1. Symptoms of excess boron on a French prune shoot.

All the leaves were collected from these trees on October 27, 1942, and were analyzed for boron by the electrometric titration method described by Wilcox (2). Saturated calomel and glass were used for electrodes. The analyses, which are included in Table II, show a tendency for the trees on myrobalan roots to accumulate the least boron. The correlation between boron excess symptoms and accumulation of boron in the leaves is not good where definite injury occurred, but this may be partly explained by the fact that a large number of leaves had fallen from some of the severely injured trees before the samples were collected.

In 1944, when the experiment was discontinued, all the trees on peach and apricot roots, with the exception of those irrigated with tap water, were dead. On the other hand, the trees on myrobalan plum roots that had been irrigated with water containing 2 parts per million and 3 parts per million boron still showed only moderate injury.

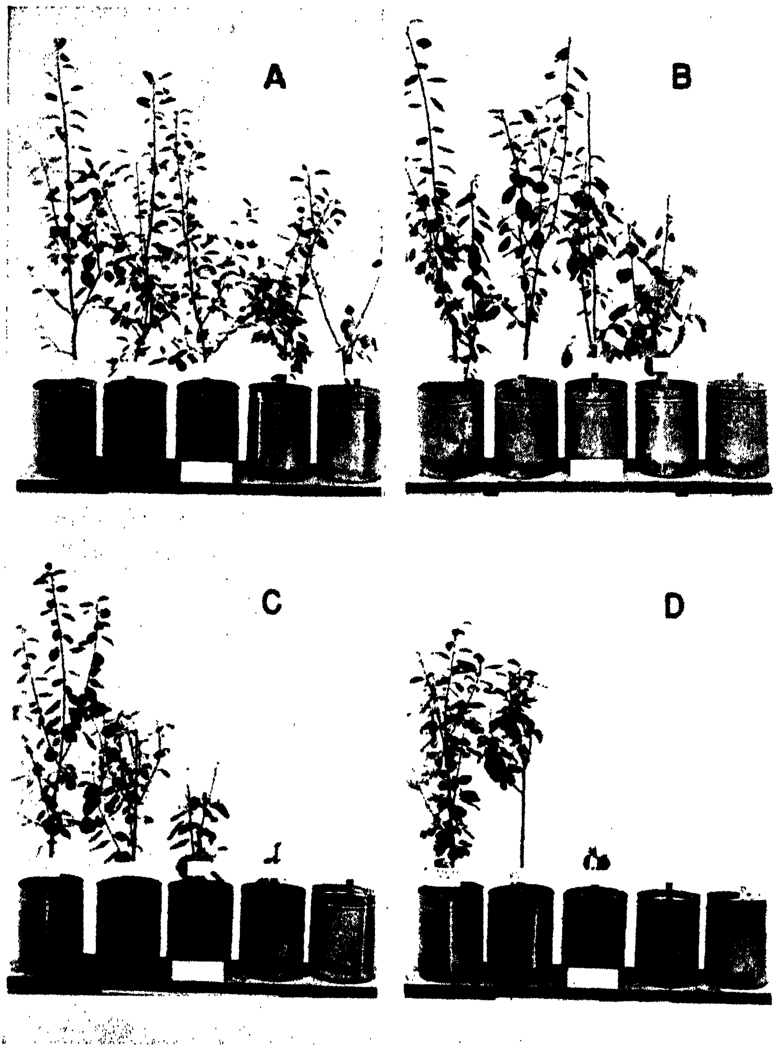

FIG. 2. Effect of excess boron on French prune trees growing on different rootstocks. A, almond roots; B, myrobalan plum roots; C, apricot roots; D, Marianna plum roots.
Irrigation waters containing the following five concentrations of boron were used for each rootstock: (Left to right) Tap water (.5 ppm), 2 ppm, 3 ppm, 5 ppm, 10 ppm.

These results, because of the small number of trees involved, are by no means conclusive, but they help to substantiate the information obtained in the following experiment, started in the spring of 1942, with French prune used as the scion variety. The procedure was es-

TABLE II—BORON CONTENT OF PRESIDENT PLUM LEAVES FROM TREES ON THREE ROOTSTOCKS (OCTOBER 27, 1942)

Irrigation Water	Boron in Dry Matter (Ppm)		
	Myrobalan Plum	Apricot	Peach
Tap water (0.5 ppm boron)	53	79	58
2 ppm boron	63	——	92
3 ppm boron	76	180	106
5 ppm boron	242	133	Dead
10 ppm boron	Dead	Dead	Dead

FIG. 3. Effect of excess boron on French-prune trees growing on peach roots. A, these five trees were irrigated with waters containing the following concentrations of boron: (Left to right) Tap water (.5 ppm), 2 ppm, 3 ppm, 5 ppm, 10 ppm; B, enlarged view of the tree irrigated with water containing 3 ppm boron.

sentially the same as that described above, except that the treatments were set up in duplicate, and the following five rootstocks were used: almond, myrobalan plum, apricot, Marianna plum, and peach (Shalil). The trees on almond, myrobalan plum, and peach roots had approximately 1-year-old tops at planting time. Those on Marianna were root-grafted at planting time, and those on apricot roots were planted as dormant buds.

Observations made on October 19, 1942, showed the French prune trees on almond and myrobalan-plum roots to be in better condition than those on apricot, Marianna, and peach roots. Leaf samples collected on October 21, 1942, (Table III) showed that the rootstock influences the absorption of boron. Trees on almond and myrobalan-plum roots which showed the least excess boron injury accumulated the least boron in the leaves.

TABLE III—Boron Content of French Prune Leaves from Trees on Five Rootstocks (October 21, 1942)

Irrigation Water	Boron in Dry Matter (Ppm)				
	Almond	Myrobalan Plum	Apricot	Marianna Plum	Peach
Tap water (0.5 ppm boron)	44	54	72	79	68
2 ppm boron	65	70	116	—	100
3 ppm boron	74	75	136	112	123
5 ppm boron	90	95	203	151	181
10 ppm boron	124	188	318	342	—

One series of trees photographed on September 9, 1943, is shown in Figs. 2 and 3. The duplicate series was nearly identical to the one shown. Trees on almond roots showed the least excess boron injury, although those on myrobalan plum were almost as good. Trees on apricot, Marianna plum, and peach roots showed considerably more injury than those on almond and myrobalan. There was a slight tendency for the trees on apricot roots to be a little better than those on Marianna plum and peach roots.

On July 17, 1944, the trees were separated into leaves and stems (trunk not included), and were analyzed for boron (Table IV). The trees on almond roots still showed the least injury and the lowest concentration of boron; those on myrobalan plum root were second best; and those on the other three stocks showed the greatest injury and the largest accumulations of boron.

TABLE IV—Boron Content of French Prune Leaves and Stems From Trees on Five Rootstocks (July 17, 1944)

Irrigation Water	Boron in Dry Matter (Ppm)									
	Almond		Myrobalan Plum		Apricot		Marianna Plum		Peach	
	Leaves	Stems	Leaves	Stems	Leaves	Stems	Leaves	Stems	Leaves	Stems
Tap water (0.5 ppm boron)	69	28	82	24	93	38	81	41	103	39
2 ppm boron	96	48	122	62	145	125	136	84	162	118
3 ppm boron	123	67	136	77	153	190	Dead	Dead	162	218
5 ppm boron	140	78	290	269	Dead	Dead	Dead	Dead	Dead	Dead
10 ppm boron	147	227	Dead	Dead	Dead	Dead	Dead	Dead	Dead	Dead

Discussion

Soil was used in these trials even though it was recognized that the boron concentrations could have been more accurately maintained in some other medium. It was thought that the soil used would provide conditions more nearly approaching those found in the orchard.

Only one type of each rootstock was used, for example, Shalil in the case of the peach. Further work will have to be done to determine if some other variety of peach rootstock, such as Lovell, will respond in the same manner.

Summary

The rootstocks used for President plum and French prune trees have a definite influence on the amount of injury caused by an excess

of boron and upon the absorption of boron by the leaves and stems. The work was done with young trees in small containers, but the differences were sufficiently great to suggest possible application to orchard plantings. Almond roots are suggested for those locations where excess boron is a problem and where other soil conditions are favorable. If the soil is too heavy or wet for almond roots it is suggested that myrobalan plum be used.

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Factors Associated with Skin-Cracking of York Imperial Apples[1]

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THE York Imperial is one of the leading varieties grown in Western Maryland and most of the Shenandoah-Cumberland region. Skin-cracking is a serious physiological disorder causing severe losses to the growers and in some years as many as 70 to 80 per cent of the fruit of a given orchard may be affected by this trouble. This disorder consists of numerous small cracks in the skin of the fruit and should not be confused with the more familiar flesh cracking as commonly observed in Stayman Winesap apple (10, 11).

Gourley and Howlett (4) stated that "... a type of lenticel cracking involving many small cracks is common in York Imperial." Reed and Crabill (6) found that skin-cracking occurred chiefly on trees under 15 years of age and "very rarely in dry seasons", but others (4, 7), made no statement limiting this disorder to any particular age of trees.

That the cracking was limited almost entirely to the green side of the fruit was noticed by Reed and Crabill (6) and by Fisher (2, 3). They also agreed that cracking was most serious under conditions of drought followed by rain which caused extensive swelling of the fruit. Reed and Crabill (6) suggested that perhaps "... the skin on the shaded side of the fruit may be actually stretched to bursting by the unusual rapid multiplication and growth of pulp cells due to a sudden increase in water supply".

Since skin-cracking of York Imperial presented difficulties in apple washing, Fisher (2, 3) while working on spray removal methods, made numerous observations on its occurrence. He stated that the tendency of fruit to crack increased as the fruit approached maturity and that it was more severe on trees low in vigor and bearing a light crop. Skin-cracks showed a tendency to run in a latitudinal direction but, if insect or some similar injury was present, cracks generally ran concentrically around the injured spot.

Schrader and Haut (7) while conducting preliminary investigations on cracking of York Imperial, also found that low vigor and light crops were conducive to cracking. They suggested that cracking may be aggravated by spray materials, especially late arsenate sprays. Their findings were not in agreement with Reed and Crabill (6) who stated that "sprayed and unsprayed fruits are affected alike".

In some fruits, structure of the cutin may have a definite correlation with cracking, as was shown by Tetley (8) who separated varieties on the basis of their cuticular characteristics and concluded that varieties having cutin "... deposited on tangential wall so that it touches the apex only of the radial wall ... are less susceptible to cracking, than

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varieties having their cutin . . . deposit extended throughout the length of radial wall or even completely surrounding the cell. . .". She also observed that periods of cold weather produce a comparatively thick and unelastic type of cuticle, which was more likely to develop cracking. This was especially true on the green side of the fruit. She found that cutin was thicker on the green side than on the red side. This is in agreement with Baker (1) who stated that on Grimes Golden apples the average thickness of the cutin on the green side was 18.0 microns, while on the red side it was only 13.3 microns. He also stated that cutin irregularity is a result of the irregular epidermal layer. More recently, Meyer (5) in a study of the skin structure of Golden Delicious Apples has shown that cracking of the cuticle is responsible for poor finish of this variety.

Material and Methods

This paper deals only with an analysis of growth and fruiting factors naturally associated with this disorder. The results of experimental treatments will be discussed in a later paper.

The investigation was carried on during the seasons of 1939, 1940, and 1941 in two separate orchards, the Potomac Highlands orchard in western Maryland and the University orchard at College Park, Maryland.

In the western Maryland orchard, two plots about one-half mile apart were selected. Trees in plot No. 1 were 27 years old and in a fair condition with skin-cracking disorder present, while trees in plot No. 2 were 25 years old and in good condition with little or no cracking disorder. All trees were set 30 feet by 32 feet apart. In the College Park orchard, trees were 9 years old and spaced 20 feet by 40 feet apart. These trees were only fairly vigorous.

Fruit samples for histological studies on thickness of cutin were collected during the harvest time of 1941. All fruit samples were picked from the east side of the trees about three-quarters of the way up the tree, but only well-exposed fruits were taken. Fruits were divided into three classes on the basis of their size. Two sections were taken from each fruit, one from the red side and one from the green side. Sections were cut out with a 5/8 inch cork borer and trimmed to approximately 1/8 inch in thickness and immediately placed in formalinacetic-alcohol fixing solution. After 2 months in this solution, six sections from each sample were run through a butyl alcohol dehydrating series and embedded in tissuemat.

Sections were cut 14 microns thick and stained in Sudan IV and Bismark Brown. Nine measurements of cutin thickness were taken on each of the six sections making a total of 54 measurements for each of the red and green sides of every fruit.

Leaf samples, as a growth index, were taken in 1941 from trees in both orchards. Two full grown leaves (fourth and fifth leaf) from 50 terminals and all leaves from 50 spurs were collected. Spur leaves were separated into small and large, counted, dried, and weighed separately. Any leaf measuring 1 1/2 inches or less from the tip to the base of the blade was classified as a small leaf.

Terminal growth measurements were made during the dormant season. Sixty measurements to the nearest 0.5 centimeter were made on each tree. All measurements were made on terminals not higher than 7 feet from the ground, and although they were selected at random, it was attempted to have them fairly evenly distributed throughout the lower portion of the tree.

Yield seemed to be definitely correlated with cracking in 1939 and in 1940, so in 1941 the actual yield record for each tree was taken. The size of the fruit also was taken into consideration, so on a few trees a bushel or more of fruit was graded into three classes: small (2⅛ inches to 2½ inches), medium (2⅝ inches to 3 inches), and large (3⅛ inches and over), and amount of cracking was determined for the fruits of each size class.

In determining the percentage of cracked fruit for a tree, a sample of fruits, picked at random throughout the tree, was carefully examined for skin-cracks and the numbers of uncracked, slightly cracked, and severely cracked fruits were recorded. A fruit was considered slightly cracked if most of the cracks were healed over and/or the area involved was not more than 20 per cent of the entire surface, a medium cracked fruit one with few open cracks and/or having not more than 50 per cent and not less than 20 per cent of its area affected, and a severely cracked fruit was any fruit with more than 15 per cent of open cracks and/or with more than 50 per cent of its surface affected by cracking. Typical samples are shown in Fig. 1. In order to have one numerical value which would indicate average severity of skin-cracking, a "cracking index" was formulated. This index was calculated by assigning a value of 0 to an uncracked fruit, 1 to a slightly cracked fruit, 3 to medium and 5 to a severely cracked fruit; these values were totaled and divided by the number of fruits in a sample. The direction of the cracks seemed to have some relationship to the main axis of growth or elongation of a fruit. In order to have a numerical measure of this tendency, 1500 cracked fruits were collected from 34 different trees and were classified into two groups: fruits which had cracks running parallel, and fruits with cracks perpendicular to the main axis of growth of the fruit.

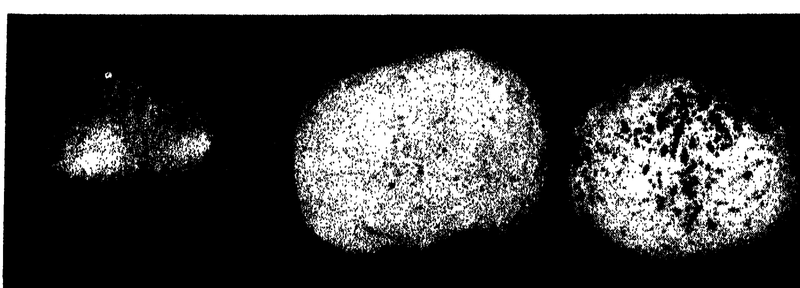

FIG. 1. Skin-cracking of York Imperial apples. Left to right normal fruit, slight skin-cracking, and severe skin cracking.

Results

Cutin Thickness:—The correlation coefficient for cutin thickness and the percentage of cracked fruits was calculated to determine the degree of relationship between these measurements. In medium-sized fruit, the correlations between percentage of cracked fruit and cutin thickness on the red side, green side and the mean of two sides were +0.661, +0.688, and +0.731 respectively. Correlation coefficient needed for significance at the 5 per cent level is 0.666, thus indicating that the only correlation not significant at this level was between cutin thickness on the red side and the percentage of cracked fruit. The calculated correlation coefficients between cutin thickness of large fruits on the red and green sides, mean cutin thickness and percentages of cracked fruit were +0.692, +0.817 and +0.782 respectively. The correlation coefficient needed for significance at the 5 per cent level is 0.707 and at the 2 per cent level 0.789. In both cases (for medium and large fruit) correlations between cutin thickness on the red side of the fruit and skin cracking were not significant. Since most cracking appears on the green side of the fruit it seems logical to assume that correlation between the cutin on the green side and cracking would be of greater importance. It may be concluded from these correlations that the relationship between cutin thickness on the green side and the percentage of cracked fruit is pronounced, and that they are indicative of a close direct relationship.

The average cutin thickness for the red and green side of medium and large sized fruits is summarized in Table I. With the exception of trees 66 and 72, cutin thickness was greater on the green than on the

TABLE I—Relationship Between Per Cent of Cracked Fruit and Cutin Thickness of York Imperial Apples (Western Maryland Orchard, 1941)

Tree No.	Per Cent of Cracked Fruit	Thickness of Cutin (Microns)*		Mean Cutin Thickness (Microns)
		Red Side	Green Side	
		Medium-Sized Fruit (2¾ to 3 Inches)		
66	82.0	16.3	16.3	16.3
67	69.0	13.3	15.4	14.4
54	59.3	14.4	15.5	15.0
76	48.1	14.2	15.5	14.8
57	36.4	14.1	14.9	14.5
62	0.0	14.1	15.9	15.0
77	0.0	13.3	13.5	13.4
72	0.0	13.3	10.5	11.9
61	0.0	10.7	11.8	11.3
		Large-Sized Fruit (3 Inches and Up)		
66	82.0	15.1	16.9	16.0
67	69.0	13.7	16.2	14.9
54	59.3	15.8	17.4	16.6
76	48.1	13.7	15.9	14.8
57	36.4	13.7	16.2	14.9
62	0.0	13.9	14.4	14.1
72	0.0	12.0	12.5	12.2
61	0.0	11.4	12.0	11.7

*Each figure represents an average of 54 measurements (Nine measurements per apple on each of the six fruits).

red side of the fruit. This is in agreement with the findings of Baker (1) who studied cutin on Grimes Golden apples.

In addition to difference in cutin thickness on the red and green side of the fruit, there was also a structural difference peculiar to each side (Figs. 2 and 3). The cutin surface on the red side was found to be much smoother and showed less irregularity than cutin on the green side. Cutin on the green side was characterized by sharp, and often deep, indentations and by irregular and distorted cells in the epider-

FIG. 2. Thin smooth cutin from the red side of York Imperial apple. Compared with Fig. 3.

FIG. 3. Thick deeply indented cutin from the green side of York Imperial apple.

mal layer. The epidermal cells on the green side often were found to be entirely separated from each other by a layer of cutin, and although this also was noticed on the red side, the separations between cells were not as frequent nor as long. Tetley (8) has found that varieties with uneven cutin, which penetrated between cells, were more subject to cracking than varieties having the cutin which touched only the apex of the radial wall of the epidermal cells. Cutin structure is apparently not only associated with skin-cracking but also is partially responsible for the subsequent poor storage qualities of affected apples.

Actual weights are not presented in this paper but Fig. 4 illustrates clearly what effect cracking has on moisture loss of fruit in storage. Fruits shown in Fig. 4 were stored under identical conditions and after 2 months in storage were removed to room temperature for 3 weeks. Sound fruits (extreme left) were still in perfect marketable condition while severely cracked fruits (extreme right) were badly shrivelled and were not marketable. This increased loss of water was undoubtedly due to cracking, but it may be partially attributed to cutin structure. It was observed that badly cracked fruit had deeply indented cutin which may also contribute toward the greater water loss.

Fig. 4. York Imperial apples after 2 months in cold storage at 32 degrees F and 3 weeks at room temperature. Left to right normal fruit — marketable; slightly cracked fruit — badly shrivelled; and severely cracked fruit — badly shrivelled and beginning to rot.

Yield Relationships:—There was a definite inverse correlation between the percentages of cracked fruits and the yields of York Imperial trees. The coefficient of correlation for plot 1 was found to be —0.570 and the coefficient of correlation required for significance at the 1 per cent level was —0.496. It may be observed in Table II that this correlation includes a few extreme exceptions present in each plot.

In plot 2, trees 26 and 27 produced exceptionally small fruit, and the size of fruit on tree 27 was smaller than on tree 26. The size of fruit accounts for the lower yield on these trees, since the yield was measured in bushels and not in number of fruits produced. Calculated correlation coefficient between the percentages of cracked fruit and the yields in plot 2 was —0.749 and the correlation coefficient needed for significance at 1 per cent level is 0.684. Obviously this negative relationship is highly significant. These findings are in agreement with Fisher (2) and Schrader and Haut (7) who also found that York Imperial apple trees bearing a heavy yield were less susceptible to this trouble.

Although there is a close relationship between the percentages of cracked fruit and the tree yields within each plot, there is a distinct difference between the two plots. In plot 1, whenever the tree yield exceeded 10 bushels there was practically no cracking, while in plot 2

TABLE II—RELATIONSHIP BETWEEN YIELD AND SKIN-CRACKING OF YORK IMPERIAL APPLES (WESTERN MARYLAND ORCHARD, 1941)

Tree	Yield Per Tree (Bu)	Per Cent Cracked Fruit	Index of Cracking
		Plot 1	
66	1.5	82.2	1.79
58	2.0	2.0	0.02
73	4.0	56.9	0.73
67	4.5	69.0	1.31
54	5.5	59.0	0.92
59	6.0	71.6	1.08
64	6.0	52.0	0.54
69	6.0	0.0	0.00
75	7.0	49.7	0.51
74	7.0	31.9	0.32
68	7.0	18.5	0.21
71	7.0	19.0	0.19
78	7.5	16.3	0.16
70	8.0	32.5	0.47
65	9.0	41.9	0.57
60	9.0	46.5	0.50
57	9.0	36.4	0.40
53	9.0	21.9	0.23
56	9.5	11.6	0.12
52	10.0	36.7	0.45
62	12.0	0.0	0.00
61	13.0	0.0	0.00
51	14.0	2.0	0.02
77	14.0	0.0	0.00
72	25.0	0.0	0.00
63	30.0	0.0	0.00
		Plot 2	
32	7.0	60.6	0.61
20	9.0	34.3	0.35
27	11.0	1.6	0.02
24	13.0	50.0	0.56
26	19.0	5.3	0.05
28	20.0	0.0	0.00
30	23.0	18.8	0.19
25	23.0	0.0	0.00
31	25.0	0.5	0.01
23	25.0	0.0	0.00
22	28.0	0.0	0.00
21	29.0	3.2	0.03
29	33.0	0.0	0.00

the yield had to exceed 23 bushels before the same effect was produced. This is probably due to a difference in vigor in trees in the two plots, for plot 1, as previously noted, was much less vigorous than plot 2.

This relationship between yields and cracking of York Imperial apples is emphasized further when biennial bearing is considered. The data presented in Table III, indicate that there is a definite fluctuation in the degree of cracking from year to year. A higher percentage of cracked fruits is always associated with the "off" year of a tree. This relationship may be partially due to the higher percentage of small fruits produced by the tree in its "on" year.

Size of Fruit and Cracking:—To determine the relationship between the percentage of small fruit (2⅛ to 2½ inches) and cracking, 20 trees from the two plots in the Western Maryland orchard were studied. Between 1 and 3 bushels of fruit were picked at random from each of these trees. The percentage of small fruit was calculated for each tree and the coefficient of correlation between the percentage of small fruit and cracking was calculated. The coefficient of correlation, —0.785, is highly significant at the 1 per cent level.

TABLE III—RELATIONSHIP BETWEEN BIENNIAL BEARING AND SKIN-CRACKING OF YORK IMPERIAL APPLES (WESTERN MARYLAND ORCHARD)

Tree No.	1939		1940		1941	
	"On" or "Off" Year	Per Cent Cracked Fruits	"On" or "Off" Year	Per Cent Cracked Fruits	"On" or "Off" Year	Per Cent Cracked Fruits
			Plot 1			
51			"Off"	56.7	"On"	2.0
61			"Off"	35.5	"On"	0.0
62			"Off"	44.2	"On"	0.0
63			"Off"	48.3	"On"	0.0
72			"Off"	30.8	"On"	0.0
77			"Off"	20.2	"On"	0.0
54			"On"	29.5	"Off"	59.3
60			"On"	15.3	"Off"	46.5
64			"On"	15.1	"Off"	52.0
67			"On"	35.1	"Off"	69.0
			Plot 2			
20	"On"	23.3	"Off"	68.9	"On"	34.3
21	"On"	11.7	"Off"	67.4	"On"	3.2
22	"On"	0.0	"Off"	38.9	"On"	0.0
23	"On"	0.0	"Off"	43.6	"On"	0.0
25	"On"	3.0	"Off"	13.4	"On"	0.0
26	"On"	0.0	"Off"	31.0	"On"	5.3
27	"On"	0.0	"Off"	54.0	"On"	1.6
24	"Off"	18.2	"On"	11.3	"Off"	50.0

All fruits from 10 trees were subdivided into small (2⅛ to 2½ inches), medium (2⅝ to 3 inches) and large (3⅛ inches and over) sizes and the percentage of cracked fruit within each of these three classes was calculated. The calculated percentage of cracking for small fruits was 10.5 ± 4.58, for medium sized fruit 43.8 ± 15.67 and large sized fruits was 61.6 ± 20.81. The standard errors compared to differences in cracking for each of these classes clearly indicate that the small fruits developed a significantly lower percentage of cracked fruit, but the standard errors of medium and large sized fruit show distinct overlapping, and statistically there is no clear separation between these two classes in their susceptibility to cracking.

Finish of Fruits:—Fruits from 11 trees, while being graded for cracking, were also graded in regard to their finish. A coefficient of correlation of —0.914 was obtained between finish and percentage of cracking. This exceptionally high negative correlation clearly indicates that fruit with smoother, waxy finish is less likely to develop skin cracking than fruit with a dry, rough finish. Under a hand-lens a fruit with poor finish was found to have many fine cracks in the cutin similar to "leather-cracking", but not visible to the naked eye.

Color of Fruit:—As stated previously, it was found that most of the skin-cracking occurs on the unblushed side of the fruit. Data presented in Table IV clearly bear out this point. Out of 1100 cracked fruits, 73.6 per cent cracked on the green side, while only 2.8 per cent had cracking on the red side alone and showed only slight cracking. It was observed that most of the cracked fruits had a yellow instead of green ground color. Fisher (2) and Reed and Crabill (6) also found that most of the cracking in York Imperial apples appeared on the shaded side of the fruit. Tetley (9) stated that on James Grieve and

Beauty of Bath apples, cracking first appeared on the green side of the fruit.

TABLE IV—The Location and Severity of Cracking in Relation to the Coloration of the Individual Fruits of York Imperial Apple (1939)

Location of Cracks Relative to Color	Per Cent of Fruit*			Total Percentage of Cracked Fruit
	Slightly Cracked	Medium Cracked	Severely Cracked	
Only on green side	60.2	11.6	1.8	73.6
On both green and red sides	14.5	6.3	2.8	23.6
Only on red side	2.8	0.0	0.0	2.8

*1,100 cracked fruits from 34 trees and three plots were examined.

Direction of Cracks:—Data in Table V indicate that 84.5 per cent of the skin cracks are perpendicular to the axis of greatest fruit growth. The cracking around healed injuries due to insect stings, was not taken into consideration because in this case cracks were concentric around the injury. Fisher (3) noticed the same relationship between location of cracking and insect injury on the fruit, and also stated that most of the cracks ran perpendicular to the axis of the apple. Schrader and Haut (7) found that the direction of the cracking was usually parallel with the ground regardless of the fruit axis, which they concluded was correlated with spray deposit at the lower edge of spray droplets.

TABLE V—Direction of Cracks Relative to the Axis of Greater Growth of Fruit (1940)

Direction of Cracks	Severity of Cracking* (Per Cent)			Total
	Slightly Cracked	Medium Cracked	Severely Cracked	
Cracks perpendicular to main axis of growth	62.7	16.8	5.0	84.5
Cracks parallel to main axis of growth	12.5	3.0	0.0	15.5

*Total of 560 cracked fruits were examined.

Growth Relations:—The relationship between the percentage of cracked fruits on a tree to the terminal growth, weight of leaves, yield per tree, cutin thickness and per cent of small fruit is presented in Table VI. The correlation coefficient representing the relations of the percentage of cracked fruit to terminal growth was found to be —0.759, to dry weight of spur leaves —0.745, to dry weight of terminal leaves —0.750, to the yield of the tree —0.839, to the mean cutin thickness +0.813 and to the percentage of small fruits —0.795. Since the correlation coefficient necessary for significance at 1 per cent level was 0.798, and 5 per cent level 0.666, it may be concluded that all of the measurements presented in this table were associated in varying degrees with the occurrence of skin-cracking.

Terminal growth measurements were taken in 1940 and 1941 on additional trees. A highly significant correlation between terminal

TABLE VI—RELATIONSHIP OF THE PER CENT OF CRACKED FRUIT TO THE TERMINAL GROWTH, WEIGHT OF LEAVES, YIELD PER TREE, CUTIN THICKNESS AND PER CENT OF SMALL FRUIT (WESTERN MARYLAND ORCHARD — PLOT 1, 1941)

Tree No.	Per Cent Cracked Fruit	Terminal Growth (Cm)	Dry Weight of Leaves From 50 Spurs (Gms)	Dry Weight of 100 Terminal Leaves (Gms)	Yield Per Tree (Bu)	Mean Cutin Thickness* (Microns)	Per Cent of Fruit Less Than 2½ Inches Diameter
66	82.0	3.08	11.32	24.45	1.5	16.2	14.3
67	69.0	7.96	23.67	34.85	4.5	14.6	5.7
54	59.3	5.18	17.68	20.05	5.5	15.8	17.3
76	48.1	8.70	20.35	34.67	7.0	14.8	15.7
57	36.4	11.67	22.90	37.95	9.0	14.7	21.8
77	0.0	7.49	19.08	36.50	13.5	13.4**	23.4
62	0.0	22.35	33.55	40.08	12.0	14.5	56.2
61	0.0	25.26	28.59	43.78	13.0	11.5	39.8
72	0.0	15.70	32.46	47.20	25.0	12.0	32.2

*The cutin thickness is a mean for red and green sides of medium and large size of fruit.
**Tree No. 77 had only medium size fruit available.

growth and the percentage of cracked fruits was obtained in 1940, but in 1941 this relationship was not nearly as pronounced. Generally, an increase in terminal growth was accompanied by a decrease in percentage of cracked fruit. On tree 62, terminal growth in 1940 average 7.8 cm and the tree produced 44.2 per cent of cracked fruit, while in 1941, the same tree had averaged 22.3 cm of terminal growth and was entirely free from cracking. There were some exceptions, as in the case of tree 77, in which the average terminal growth was reduced from 23.3 cm in 1940 to 7.5 cm in 1941, but the percentage of cracking was also reduced from 20.2 in 1940 to 0.0 per cent in 1941. In general, however, most of the trees showed a decrease in the percentage of cracked fruit produced, whenever the average terminal growth was increased.

Some partial correlations were determined on the data presented in Table VI. It was interesting to note that when terminal growth and cutin thickness were kept constant, the correlation between the percentage of cracked fruit and the yield was increased from —0.839 to —0.964 indicating that whenever cutin thickness and terminal growth are the same on a number of trees, yield is a determining factor in causing cracking. On the other hand, if terminal growth and yield are kept constant, the correlation between cutin thickness and the percentage of cracked fruit is greatly reduced, thus indicating that cutin thickness depends on conditions favoring terminal growth and high yield, and that its relation to cracking is in reality due to the close relationship of cracking to yield and terminal growth.

DISCUSSION

Why do apples from one tree develop skin-cracking, while the fruit on another tree remains uncracked?

Various characteristics of the cracked and uncracked fruits are summarized in Table VII. The uncracked fruit was characterized by a deep green ground color, greenish flesh, smooth waxy finish, small to medium size, and the ability to hang on the tree for 2 or 3 weeks after the commercial harvest date. The cracked fruit, however, had a yellow-

ish green, or more often, yellow ground color, yellowish flesh, rough, dry finish, medium to large size, and dropped badly even before the time of normal harvest.

TABLE VII—TREE AND FRUIT CHARACTERISTICS ASSOCIATED WITH CRACKED AND NON-CRACKED FRUIT OF YORK IMPERIAL APPLES

	Characteristics Associated With Non-Cracked Fruits	Characteristics Associated With Cracked Fruits
	Tree Characteristics	
Vigor:	Medium to good	Medium to poor
	Long thick terminal growth	Short thin terminal growth
	Large leaves	Medium to small leaves
	Dark green foliage	Green to light green foliage
	Heavy crop	Light crop
	Fruit Characteristics	
Size:	Small to medium	Medium to large
Color:	Green ground color	Yellow green to yellow ground color
Finish:	Smooth and greasy	Rough and dry
Maturity:	Matures later	Matures earlier
Dropping:	Hangs until late fall	Drops easily at harvest time or before
Storage:	Keeps well	Shrivels and develops rots
Cutin:	Thinner, smoother	Thicker, rougher, with indentations

On the basis of these characteristics, uncracked fruit appeared to be in a highly vegetative state and the cells probably had not lost their elasticity or resistance to excessive stretching, whereas, cracked fruit had passed this growth stage and possibly the cells were no longer capable of further growth or excessive stretching, resulting from the intake of water and nutrients in the later part of the growing season. It is suggested that these differences may be due to the continuous vegetative condition in the fruit of the first type and premature cessation of growth in the fruit of the second type. One should not draw the conclusion that the separation of the fruit into these two types is very exact. On the contrary, there were fruits which exhibited mixed characteristics of both types with varying degrees of cracking; there were also some exceptions in each type, but in general, this classification was true.

The percentage of cracked fruit was always higher in the "off" year, however, the actual number of bushels produced per tree was not the only factor affecting the susceptibility of fruit to cracking, for the condition of the tree in its "on" and "off" years was also exerting some influence. Another factor was found to be the size of the fruit. Small-sized fruit rarely cracked, and from observations it was concluded that the low percentage of small-sized, cracked fruit was mainly due to its active state of growth and not to the size.

It was found that the thickness of cutin was statistically correlated to the cracked fruit and poor finish. These findings parallel closely those reported by Meyer (5) who correlated the thickness and structure of apple skin with its finish. It is interesting to note that cutin formation was smoother, thinner, and more regular on the blushed side where cracking was of minor occurrence. The epidermal and subepidermal layers of cells also exhibited pronounced irregularities in shape and arrangement on the green side of the fruit. It is suggested

that these irregularities of cutin formation and of tissues immediately underneath the cutin may influence the susceptibility of the fruit to cracking. Presumably thin, smooth, continuous cutin with a more regular epidermal layer is more resistant to the stress caused by the internal increase in volume than the thick cutin with indentations often penetrating between the epidermal cells which are pulled apart and otherwise distorted. It may be that this latter condition could be referred to as a precursor of cracking. It is realized that some measurement of the relative activity of cells should have been taken in order to determine definitely if a difference in physiological age was actually present in these different types of fruit.

Summary

1. The red side of the fruit, which is less subject to skin-cracking, possessed thin, regular cutin and showed little distortion of the epidermal and sub-epidermal layers of cells. The cutin on the green side was thick, irregular, and the epidermal and subepidermal layers of cells showed much distortion. A significant positive correltion was found to exist between thickness of cutin and the percentage of cracked fruits on a given tree.

2. Trees with heavy crops were less susceptible to skin-cracking. Biennial bearing had a definite relation to skin-cracking. A higher percentage of cracked fruit was found in the "off" year than in the "on" year.

3. Small, highly finished fruit with a deep green ground color was less susceptible to skin-cracking.

4. Yellow or yellowish green part of the fruit was the most susceptible to skin-cracking, green part was next and the red side was the least affected.

5. Majority of skin-cracking were found to be perpendicular to the axis of the greatest fruit growth.

6. Fruits on highly vigorous trees were less susceptible to skin-cracking. The terminal growth and foliage development were inversely related to the percentage of cracked fruit.

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Field Nursery Tests with Newly Harvested and One- or Two-Year Stored Lovell Peach Seed[1]

By Karl D. Brase, *New York State Agricultural Experiment Station, Geneva, N. Y.*

Peach pits[2] of a California drying variety, the Lovell, have in recent years been used as a seed source for peach seedling rootstocks. Large quantities of Lovell pits are available and the seedlings grown therefrom are sufficiently different from most of the peach varieties now propagated that they can be readily distinguished from the budded tree. This paper is a preliminary report of tests to determine the effect of dry storage for 1 and 2 years on the retention of viability of the seed and on the growth of the seedlings from such seeds.

Materials and Methods

Lovell peach pits of the 1944 harvest, stored dry in an open shed for 1 year and of the current harvest year were obtained in the fall of 1945.[3] After soaking in water for 24 hours, 4,000 pits of each lot were planted in shallow trenches in the nursery. Each trench was covered with a layer of moist peat moss, and with 5 to 6 inches of soil ridged over the moss. The ridge was smoothed down in early spring so that only a few inches of soil was left as a cover for the seed. The remaining pits of the original shipment were stored in closed steel drums in a well-ventilated shed, to be used in subsequent years.

In mid-December 1945 lots of 2,300 and 2,400 pits of the 1944 and 1945 harvest respectively were taken from the steel drums, soaked for 24 hours in water and stratified for after-ripening in moist clean pine sawdust at a temperature of 35 to 40 degrees F. At the end of a 120-day period, each lot was inspected. Sprouted seeds were sorted out and immediately planted in the nursery row, with the same treatment as in the previous year. Pits which had not cracked naturally after 140 days were cracked mechanically. Poor seeds were discarded and sound ones were planted.

Additional pits of the 1946 harvest were obtained in early October 1946. Lots of 1,000 each of the 1944, 1945 and 1946 harvest year were planted the same way and the remaining newly-harvested pits stored in the manner previously described. Also, beginning in mid-December, identical lots, as used for fall planting, were after-ripened, and on completing a 120-day period examined and sprouting seeds at once planted. Pits which had not cracked were handled the same way as in 1946.

For comparison with the Lovell, 1-year-old "Carolina Natural" pits were included in the 1946–47 test. To determine the approximate

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[1]Journal Paper No. 741 of the New York State Agricultural Experiment Station.

[2]In this paper the term "pit" is used to denote the stony pericarp and inclosed seed, and the term "seed" when the seed is separated from the stony pericarp.

[3]The writer is indebted to the Kelly Nursery Company, Dansville, New York, for supplying pits.

germination, tests by the excised embryo method (2) were made prior to fall planting in 1945, 1946 and 1947.[4]

Results

Condition of the Pits from Different Harvest Years:—Differences existed in the quality of pits from each harvest year and judging by the appearance and percentage of split pits present, lots harvested in 1944 and 1946 were superior to those of 1945. In a sampling of 7,500 seeds from the 1944 harvest, 2.4 per cent were found with split pits; 5.7 per cent of a sample of 6,895 of the pits from the 1945 harvest were graded out as worthless. Lots obtained in 1946 and 1947 were of excellent quality.

There also occurred weight loss during dry storage. Such loss was greatest during the first year of storage. In 20 different samplings a difference of 6 ounces per 500 pits was found. The same number of newly-harvested, but dry pits weighed 5 pounds 6 ounces, whereas those that had been stored for 1 year weighed only 5 pounds. There was only a very slight weight loss under the storage method employed during the second storage year.

Germination by the Excised Embryo Method:—Germination tests by the excised embryo method, made before fall planting, indicated a rather rapid decline in the germination of Lovell pits when stored dry over a 2-year period (Table I). After 3 years of dry storage none

TABLE I—Germination Test of Peach Pits by the Excised Embryo Method

Harvest Year	Percentage Germination and Growth Response		
	Fall 1945	Fall 1946	Fall 1947
Lovell			
1944	68, Fair	26, Weak	0
1945	75, Strong	56, Fair	11, Weak
1946		92, Strong	48, Fair
1947			82, Strong
Carolina Naturals			
1945		42, Fair	13, Weak

of the excised seeds showed growth responses. In all viable seeds of newly-harvested pits the plumule developed into a shoot and the radicle into a root. Similar growth responses, although in fewer instances, occurred with viable seeds after 1 year of storage. After the second year in storage, growth responses of viable seeds were weak and in no case did shoot growth occur.

Seedling Stands from Fall-Planted Pits:—During the two test years, fall-planted newly-harvested Lovell pits that had not been previously after-ripened in moist sawdust gave the best stands in the nursery row (Table II). The stand from 1-year-old pits stored dry was 12 per

[4]The germination tests were made by C. E. Heit, Seed Investigations Division, New York State Agricultural Experiment Station, Geneva, New York.

TABLE II—STAND OF PEACH SEEDLINGS OBTAINED FROM FALL-PLANTED PITS NOT ARTIFICIALLY AFTER-RIPENED

Harvest Year	No. Pits Planted	Per Cent Stand
Lovell Test Year 1946		
1944	4,000	34.7
1945	4,000	47.0
Lovell Test Year 1947		
1944	1,000	18.5
1945	1,000	38.7
1946	1,000	71.8
Carolina Naturals		
1945	1,000	43.7

cent lower in 1946 than that from newly-harvested ones. The second test year showed a further decline with a stand of 16.2 per cent less than in 1946. At the same time the stand from pits of the 1945 harvest, after 1 year of dry storage was 8.3 per cent lower than the previous year. One thousand pits of the current harvest (1947) produced 718 seedlings. One-year-old "Carolina Natural" pits giving an approximate germination test of 42 per cent by the excised embryo method, produced when fall planted, 437 seedlings, or a stand about as good as the germination test indicated. Usually the germination test indicates a germination better than actually obtained in the field.

Stands from Spring-Planted, After-Ripened Seeds:—Fall planted pits naturally after-ripened in the nursery row gave better seedling stands than did artificially after-ripening and planting the sprouting seeds in the spring. Thus, in 1946, stands in the nursery row were 10 per cent lower with 1-year-old seed and 7.7 per cent lower with new seed than stands from fall planting. In 1947, seedling stands of the Lovell were, with 2-year-old seed, 15.1 per cent lower; with 1-year-old seed, 27.1 per cent lower; and with new seed, 22.8 per cent lower than those of fall-planted pits. After-ripened "Carolina Natural" 1-year-old gave a 12.6 per cent lower stand than when fall planted.

Growth of Seedlings in the Nursery Row:—In both test years, newly-harvested seed showed earlier seedling emergence than seed stored 1 and 2 years respectively. Furthermore, during the early part of the growing season, seedlings from new seed showed greater vigor than those from 1- and 2-year-old seed. Such differences in vigor were also noticed in the excised embryo germination tests. Beginning with the middle of July the growth differences gradually disappeared, and at budding time in early September all seedlings appeared uniform in height. Evidently the greater number of seedlings per foot of row from newly-harvested Lovell seed was responsible for the fact that these seedlings did not maintain their earlier advantage.

DISCUSSION

The tests indicate that the viability of Lovell pits decreases with age during dry storage and that pits stored for more than 1 year have a reduced planting value. It is also shown that fall planting gave better

seedling stands during two successive test years. So far as labor is involved fall planting of pits is easier than planting after-ripened sprouting seeds in the spring. Furthermore, danger from contamination is less in fall planting since in the planted row the individual pits are not in contact with each other as during stratification for after-ripening. Once the seed has been after-ripened it appears to be very susceptible to disease. Contamination is more likely to occur if seeds must be disturbed and transferred from the after-ripening medium to the soil (1). As seen from Table III, field planting of apparently healthy sprouting seeds gave at best only a 75 per cent survival.

The Lovell variety has a relatively long after-ripening requirement (3). A large number of after-ripening pits do not crack after 120 days of stratification. The number of cracking pits and sprouting seeds is again directly related to the age of the pits used. Thus, 1,000 pits of the 1946 harvest when after-ripened for 120 days produced 664 sprouting seeds in the spring of 1947, whereas the same number of 1- and 2-year-old pits treated in an identical way gave only 170 and 92 sprouting seeds respectively at the same date. Similar observations have been reported with Elberta pits (4).

TABLE III—GERMINATION AND STAND OF LOVELL AND CAROLINA NATURAL PEACH SEEDLINGS OBTAINED FROM SPRING-PLANTED SEEDS ARTIFICIALLY AFTER-RIPENED

Harvest Year	No. Pits After-Ripened	Cracked and Sprouted After 120 Days (Per Cent)	Hand Cracked		Per Cent Seedling Stand		
			Decayed Seed (Per Cent)	Sound Seed (Per Cent)	Cracked Sprouted Seeds	Hand Cracked Sound Seeds	Total of After-Ripened Pits
			Lovell, Test Year 1946				
1944	2,300	13.0	20.7	66.3	60.5	25.2	24.7
1945	2,400	60.0	23.4	16.6	59.0	24.3	39.3
			Lovell, Test Year 1947				
1944	1,000	9.2	66.0	24.8	22.0	5.2	3.4
1945	1,000	17.0	18.5	64.5	59.5	2.3	11.6
1946	1,000	66.4	11.6	22.0	74.0	0.0	49.0
			Carolina Naturals, Test Year 1947				
1945	1,000	39.9	38.7	21.4	76.0	3.7	31.1

Seeds which after 140 days of after-ripening have to be excised from the stony pericarp appear to be, even if sound, of doubtful planting value. Weather and soil conditions, no doubt, influence the stand of seedlings from such excised sound seeds (Table III). The test year 1946 furnished ideal weather and soil conditions in the spring, but only a 25 and 24 per cent seedling stand was obtained from excised, sound and after-ripened seeds. In the spring of 1947 weather and soil conditions were very adverse and seedling stands were affected correspondingly. Thus, seedling stands from excised seeds were from 5 per cent to 0.

Although having been tested for only one year, it appears that the loss in viability during dry storage is less with "Carolina Natural" pits than with pits of the Lovell variety.

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Some Effects of Pruning Severity and Training on Fredonia and Concord Grapes

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PARTRIDGE (2, 3), Shepard (4), and Colby and Tucker (1) have reported on the need for balanced pruning and have shown some of the effects of unbalanced pruning with Concord grapes.

Attention to the importance of pruning severity in Concord grapes has been less than that given to studies on training systems. In 1925 Partridge (2) published a scale he used to relate the bud number left at pruning to the pounds of prunings removed. This afforded 30 buds to a vine yielding 1 pound of prunings and eight buds for each additional pound. This scale has also been used successfully for experimental plantings in Ontario, Canada, in Pennsylvania and in New York.

No comparisons have been published on the effects of varying degrees of severity of pruning which are based on vine vigor. Many trials have been made using various fixed numbers of buds as 40, 60 and 80 per vine (4, 5).

Recent observations have shown that the Fredonia grape frequently has loose clusters and a poor yield on vigorous vines. To investigate this, a 1-acre vineyard of the Fredonia variety planted in 1935–37 and growing at the Vineyard Laboratory, Fredonia, New York was used. It is growing on Fulton silty clay loam. Twenty-four rows of 29 vines spaced 8 feet by 8 feet make up the experimental material. This is divided into 12-row replicates each of which has four 3-row training blocks, Chautauqua, 6-cane Kniffen, 4-cane Kniffen and Umbrella. The three rows for any one training are pruned at three levels of severity. As a base, the scale suggested by Partridge is used; 30 buds for the initial pound of prunings and eight for each additional pound is the severity for one row. A second row is pruned so that 20 buds are left for the initial pound of prunings and eight for each additional pound; this is heavy or severe pruning. A third row is pruned so that 40 buds are left for the initial pound of prunings and eight for each additional pound.

The training treatments were established in Block I (the 12 east rows) by Dr. T. A. Merrill[1] in 1942. The pruning severity was determined by an experienced pruner, no counting was done. In the spring of 1945, Block II was trained to the four systems and the severity of pruning treatments were started on both blocks. In weighing the prunings, only one-year wood was used and this weighed in tenths of a pound. The buds left as renewal spurs are included in the total bud count.

In this study, all the buds chosen were from high quality wood, as judged by diameter and internodal length. We have added this matter of controlled severity to that of choosing quality wood.

[1]Grateful acknowledgement is made to Dr. Merrill for the 1942 records, and to Dr. M. T. Vittum for assistance in the statistical analyses.

Presentation of Data

It was the large variation in pruning severity in this block in 1944 which really prompted the systematic comparison of these levels of pruning severity. In one row trained to Chautauqua, the pruning severity ranged from 12 buds[2] to 42 buds per pound. There was a fairly even distribution of the vines in the range 20 to 40 buds per pound. The yield data for the training systems when expressed as pounds per vine are in a different order when a weighting is done for the variation in pruning severity. The tendency of the pruner was to have a rather uniform bud number per vine; weak vines were under-pruned but the over-pruning of the vigorous vines was most noticeable.

At each harvest, the yield of each vine was weighed. These data, presented as means per vine, are given in Tables I and II.

TABLE I—Yield of Fredonia Grapes in Pounds per Vine 1942–1947

Treatment	1942	1943	1944	1945	1946	1947
20-bud	—	—	—	0.7	7.5	9.1
30-bud	—	—	—	1.2	10.5	12.0
40-bud	—	—	—	1.3	14.2	14.3
Chautauqua	6.2	0.8	9.7	0.8*	10.7	10.2
Umbrella	5.4	2.2	14.2	1.3	11.8	12.6
4-cane	3.3	2.8	16.0	1.1	10.6	13.0
6-cane	9.3	3.1	14.5	1.1	10.5	11.4

*For Block I. All data for 1942, 1943 and 1944 are from Block I.

TABLE II—Relative Yield of Fredonia Grapes 1942–1947

Treatment	1942	1943	1944	1945	1946	1947	Mean
20-bud	—	—	—	58	71	76	68
30-bud	—	—	—	100	100	100	100
40-bud	—	—	—	108	135	119	121
Chautauqua	188	29	61	73*	101*	78	83
Umbrella	164	79	89	118	111	97	109
4-cane	100	100	100	100	100	100	100
6-cane	282	110	91	100	99	88	92

*For Block I. All data for 1942, 1943 and 1944 are for Block I.

Table III presents the 1947 yield data and their statistical analysis.

TABLE III—Fredonia Grape Yield Data for 1947 (Expressed as Pounds per Vine)

Training System	20 Buds Per Pound		30 Buds Per Pound		40 Buds Per Pound		Mean for Training
	Block I	Block II	Block I	Block II	Block I	Block II	
Chautauqua	9.3	7.1	9.5	9.4	11.5	14.4	10.2
6-cane Kniffen	10.5	6.3	14.4	9.4	14.4	13.4	11.4
4-cane Kniffen	11.7	9.5	15.4	12.8	15.3	13.2	13.0
Umbrella Kniffen	8.7	9.6	12.7	12.4	16.9	15.0	12.7
Mean for pruning severity	9.1		12.0		14.3		

At the 0.5 per cent level the least significant difference is 1.62 for the training system comparison and 2.00 for the severity of pruning comparison.

[2]Hereafter in this paper the term "x buds per pound" means "x buds for the initial pound of one year prunings and eight buds for each additional pound".

At the time of pruning the vines, the one-year wood weights were recorded. The means for those pruning weights are presented in Table IV. It seems obvious that the largest fluctuation is due to the season. For 1946 there is a reduction in pruning weight in those vines pruned to 40 buds per pound. This reduction was not sufficient to prevent the light pruning treatment to carry more buds in 1947 and yield the most grapes.

TABLE IV—AVERAGE WEIGHT OF PRUNINGS PER VINE (DATA ARE RECORDED FOR AUTUMN OF THE INDICATED YEAR)

Training System	20 Buds Per Pound				30 Buds Per Pound				40 Buds Per Pound			
	1944	1945	1946	1947	1944	1945	1946	1947	1944	1945	1946	1947
Chautauqua*	0.9	1.9	2.0	2.7**	1.1	2.1	1.6	2.9	1.0	2.3	1.5	2.3
Umbrella	1.2	2.5	1.9	3.0	1.0	2.6	1.8	3.4	0.9	2.3	1.8	2.4
4-cane	0.9	2.7	2.3	2.9	0.9	2.7	2.1	3.4	0.9	2.5	1.9	3.7
6-cane	0.9	2.5	2.3	2.6	1.0	2.8	2.6	3.5	0.9	2.9	2.1	3.7

*For 1945 and 1946 only Block I data are used for the Chautauqua system.
**All 1947 pruning data are means of samples of six vines from each of 24 rows.
Yield expressed on the basis of 100 buds or 100 shoots.

In order to answer the question regarding productivity per shoot, calculations were made of the yield per 100 buds for each vine as well as the yield per hundred bearing shoots at harvest time. For 1946 the data are presented in Table V.

TABLE V—BUD COUNT AND YIELD OF FREDONIA GRAPES 1946 AND 1947 (BUDS PER POUND OF PRUNINGS)

	1946			1947		
	20	30	40	20	30	40
Buds/vine	32.0	44.0	53.0	29.0	38.0	46.0
Yield/vine	8.0	10.8	13.7	9.1	12.0	14.3
Yield/100 buds	25.0	24.6	26.0	31.4	31.5	31.0
Shoots/vine Jun 7, 1946	25.0	31.0	37.0	—	—	—
Yield/100 shoots	32.0	35.0	37.0	—	—	—
Yield/100 shoots (post harvest count)	42.0	49.0	62.0	38.0*	42.3*	45.5*

*In an analysis of variance of the 1947 data the L.S.D. at the 5 per cent level was 3.7; at the 1 per cent level it was 5.4. In 1947 the effect of training systems expressed on this basis was not significant.

These data indicate that the production per 100 buds left at pruning time is nearly constant for the three levels of pruning severity. They show, too, that as pruning severity is increased the production per 100 shoots (present at harvest) is significantly decreased.

As an indication of the productiveness of the shoots pruned to the varying levels of severity, the 170 vines trained to Umbrella were classified with respect to the number of buds on the vine at pruning time, the severity of pruning, and the yield. Table VI shows these data.

These data show that the severity of pruning was important in affecting yield in a manner independent of the effect of total bud number on yield.

In all of these data on yield in its relation to bud number or shoot number, it is well to remember that the difference between the number of buds at pruning time and the number of shoots at harvest is great.

TABLE VI—MEAN YIELD IN POUNDS PER VINE OF UMBRELLA-TRAINED FREDONIA GRAPES (1946)

Pruning Severity	Mean Bud No. Per Vine (at Pruning Time)						
	23	28	33	38	43	48	53
20 buds/pound	7.1	8.5	9.1	10.9	9.8	—	—
30 buds/pound	—	—	8.6	13.7	14.5	12.4	16.7
40 buds/pound	—	—	—	14.4	12.9	14.8	19.4

In 1947 this reduction was 5, 9, and 15 for pruning severities of 20, 30, and 40 buds per pound respectively. Based on the pruning-time counts, these losses on a percentage basis are 18, 25, and 33 for the three levels of severity. The effect of training method on this reduction was slight.

In 1946 and 1947 the size of clusters borne by each vine was recorded. These data for 1946 are presented in Table VII.

TABLE VII—CLUSTER SIZE IN POUNDS PER CLUSTER OF FREDONIA GRAPES IN 1946

Training System	20 Buds/Lb.		30 Buds/Lb.		40 Buds/Lb.		Mean for Training
	Block I	Block II	Block I	Block II	Block I	Block II	
Chautauqua	0.131	—	0.149	—	0.174	—	0.151
Umbrella	0.175	0.176	0.183	0.178	0.185	0.184	0.180
4-cane	0.156	0.177	0.153	0.162	0.159	0.167	0.161
6-cane	0.155	0.160	0.149	0.145	0.150	0.162	0.154
Pruning mean	0.166		0.162		0.168		

When the analysis of variance is used with these data (exclusive of the incomplete Chautauqua data) it is found that the effect of training system on cluster size is statistically significant. Umbrella training is superior at the 5 per cent level to each of the other two Kniffen systems.

In 1947 the order of cluster size with respect to training system was identical to that in 1946 but the differences were not significant. The mean cluster size in 1947 was 0.171 pounds per cluster.

In both 1946 and 1947 there were only insignificant differences in berry weight.

If there are not large differences in cluster size nor in berry size then the yields are likely to be affected by differences in numbers of clusters.

In 1945 detailed counts were made of the relation between the length of the basal six internodes and the number of clusters which had abscissed from that shoot. It was considered that the length of the basal six internodes would be an index of the vigor of that shoot at the time when food could have limited berry or cluster set. A stub of the cluster stem was a clear indication of the former presence of a cluster on that shoot. Many shoots had lost two or three clusters. Table VIII presents this relation of shoot length and cluster abscission.

These data show that with increasing shoot length there was more severe cluster abscission.

There are several means of reducing the number of extremely vigorous shoots other than starving the vine. Such ways are an increase

TABLE VIII—THE LENGTH IN INCHES OF THE SIX BASAL INTERNODES ON FREDONIA GRAPE VINES OF FOUR CLUSTER-ABSCISSION CLASSES (1945)

Training and Severity	Clusters Abscissed Per Shoot				Total No. of Shoots
	0	1	2	3	
6-cane 40	15.0	16.0	17.6	17.6	124
Chautauqua 40	14.3	16.7	16.7	16.7	97
Umbrella 40	15.3	15.4	17.0	17.3	115
Umbrella 20	16.0	17.5	18.3	19.2	79
6-cane 20	18.4	18.6	20.0	19.6	73
Weak vines	12.2	14.2	16.4	No shoots	65

in shoot number, or a bending of the fruiting cane as in a properly tied Umbrella-trained vine. The increased shoot number affords a larger leaf surface per vine prior to bloom than would be present if the shoot number was reduced.

In 1946 mean number of clusters per bearing shoot was calculated. For the 20-, 30-, and 40-bud pruning severities the clusters per shoot are 2.7, 3.0 and 3.5 respectively. For the Umbrella, 4-cane, and 6-cane training the data are 3.4, 3.3 and 2.8 respectively. The effect of pruning severity on cluster number per shoot is statistically significant at the 5 per cent level; that of training systems is not found to be so even though the differences between means are much greater. The plot technique affords two replicates for training systems and eight for pruning severity.

These same three pruning severities were first used on Chautauqua-trained Concord vines in 1947. At least 225 vines were used for each of these pruning treatments. The mean yields per vine for pruning severities of 20, 30 and 40 buds per pound were 8.5, 11.9 and 14.5 pounds respectively. The cluster sizes were similar for each pruning severity. The vines pruned most severely had vine growth which had many secondaries and was long continued. The fruit from the three treatments had the same sugar content late in the season; that from the 20-bud severity reached its highest sugar content earlier than did the fruit from the vines pruned to 40 buds per pound of prunings.

FRUIT SET RELATED TO PRUNING TREATMENT

The effect of severity of pruning on the setting of fruit in some varieties of vinifera grapes was studied by Winkler (6, 7, 8). He reported that flower clusters of closely-pruned vines of some varieties set a smaller proportion of berries than did the clusters on vines receiving long pruning. A smaller percentage of the pollen from clusters on closely-pruned vines germinated on artificial media than of the pollen from vines receiving light pruning or no pruning.

A study was made of the effect of the degree of pruning severity on the fruit setting tendency of Fredonia vines in 1946 and in 1947. Clusters of blossoms on vines pruned at different levels of severity were self-pollinated and pollinated with pollen from Fredonia vines pruned at different levels of severity and with pollen from a vigorous growing staminate vine. The self-pollinated clusters were covered with paper bags before anthesis and the florets allowed to self pollinate. The florets of the clusters pollinated with pollen from other vines

were emasculated with fine-pointed forceps. They were pollinated when receptive with pollen from freshly-gathered clusters which were shedding pollen profusely. The pollinated clusters were then covered with paper bags which were not removed until the clusters were harvested.

The results of the 1946 pollinations are presented in Table IX. These data show that the pollen of a staminate flowered rootstock was much more effective in setting fruits on both Fredonia and Concord than was pollen of these respective varieties. There is some indication that clusters on Fredonia vines receiving spur pruning set a smaller proportion of berries than did clusters on vines receiving normal pruning or those which were not pruned. The limited observations on Concord which were included in the study did not indicate that the fruit setting tendency of the latter was influenced by difference in the degree of pruning severity.

TABLE IX—THE INFLUENCE OF THE DEGREE OF SEVERITY OF PRUNING ON THE SET OF FREDONIA AND CONCORD GRAPES AT FREDONIA, NEW YORK (1946)

Pruning of Seed Parent	Pruning of Pollen Parent	Pollinated		No. Clusters Setting	Per Cent Florets Setting	Average Weight Per Berry (Gms)	Per Cent Florets Set
		Clusters	Florets				
Spurred Fredonia	Self pollinated	9	1,227	4	3.4	3.77	
	Normal Fredonia	3	276	1	5.6	2.98	
	Unpruned Fredonia	3	175	0	—	—	3.5
	Staminate flowered vine	4	405	2	15.8	3.73	
	Normal Concord	1	95	0	—	....	
	Spurred Concord	1	180	1	2.8	2.94	
Normal Fredonia	Self pollinated	6	1,220	4	5.5	4.05	5.2
Unpruned Fredonia	Self pollinated	7	1,235	6	8.3	3.40	
	Spurred Fredonia	5	550	2	3.2	2.30	
	Normal Fredonia	3	400	1	1.2	2.98	9.9
	Staminate flowered vine	4	460	4	28.7	3.47	
	Concord	1	160	1	13.6	3.23	
Spurred Concord	Self pollinated	5	660	5	30.3	2.21	26.8
	Staminate flowered vine	2	195	2	48.7	2.56	
Normal Concord	Self pollinated	2	375	1	18.1	2.06	18.1
Unpruned Concord	Self pollinated	4	563	4	15.9	1.56	
	Normal Concord	2	92	0	—	—	15.7
	Spurred Concord	1	140	1	7.8	2.06	
	Staminate flowered vine	1	140	1	33.5	1.85	

In 1947 pollinations were made on vines of Fredonia which were pruned and thinned to about four vigorous shoots per vine, on vines having 10 shoots per vine and on vines pruned to a normal level of 28 to 36 shoots per vine. Emasculations and pollinations were conducted as in 1946 with pollen from each of the three levels of pruning severity and from Constantia a staminate flowered rootstock vine which blossomed at the same time as Fredonia. Table X presents the results.

These data indicate that self-pollinated florets of closely pruned Fredonia vines set a smaller proportion of berries than do the florets of vines receiving less severe levels of pruning. There is some indica-

TABLE X—THE INFLUENCE OF THE DEGREE OF SEVERITY OF PRUNING ON THE SET OF FRUIT OF FREDONIA GRAPES AT FREDONIA, NEW YORK (1947)

Pruning of Seed Parent	Pruning of Pollen Parent	Pollinated		No. Clusters Setting	Per Cent Florets Set	Average Weight Per Berry (Gms)	Average Number Seeds Per Berry	Per Cent Florets Set
		Clusters	Florets					
Close pruned	Selfed	18	2,655	12	5.1	3.58	1.49	
	10-bud	7	659	7	26.4	3.55	1.57	17.8
	Long pruned	7	867	7	28.9	3.86	2.40	
	Constantia	10	919	10	37.8	4.60	2.44	
10-bud	Selfed	13	2,295	13	11.5	3.85	1.95	
	Close pruned	5	707	4	15.7	3.78	1.40	16.2
	Long pruned	3	431	2	7.6	4.15	1.56	
	Constantia	6	811	6	34.4	4.67	2.05	
Long pruned	Selfed	9	1,895	9	11.5	3.64	2.00	
	Close pruned	5	590	4	11.8	4.78	1.40	16.8
	10-bud	4	499	4	27.9	3.82	1.93	
	Constantia	4	450	4	34.2	4.60	2.67	

tion that the pollen from closely pruned vines may be less effective in producing set of fruit than the pollen from less severely pruned vines. Pollen from the staminate flowered Constantia vines set a greater proportion of berries than any source of Fredonia pollen. The data on average number of seeds per berry show that pollen from closely pruned vines of Fredonia produced appreciably lower seed content per berry than did pollen of other sources regardless of the pruning severity level of the seed parent. The data on berry weight show a similar trend. There was no appreciable difference in the total per cent of florets set on the vines pruned to different levels of severity. In view of these findings it appears that the decreased fruit setting tendency shown by closely pruned vines of Fredonia is the result primarily of some influence on the pollen which renders it less capable of functioning in the processes of fertilization. The anthers of florets from such vines dehisced normally and produced pollen though in less abundant amounts than the anthers from vines pruned less severely. The pollen from severely pruned vines showed an appreciably greater proportion of shrivelled grains when studied under the microscope.

SUMMARY

Three year's data from a trial of four training systems and three pruning severities for Fredonia grapes are recorded. They show that there is a large increase in production as the severity of pruning is decreased from 20 buds for the initial pound of prunings to 40 buds for the initial pound of prunings. In terms of production, the training systems can be ranked in the order Umbrella Kniffen, 4-cane Kniffen, 6-cane Kniffen and Chautauqua. Upon analysis, the data show these causes for the yield differences:

1. There are more shoots to bear grapes on the lightly pruned vines.
2. There are more clusters per shoot on the lightly pruned vines and on the Umbrella trained vines.
3. In 1946, the cluster weight was greater with Umbrella training than the other three systems.

The weight of wood produced in 1947 is the largest of any year since the start of the experiment. The light pruning has not resulted in a decline of vine vigor.

The pollen from Fredonia grape vines receiving severe pruning was less effective in producing set of fruit and in production of seeds per berry than the pollen of Fredonia vines pruned less severely or the pollen of two staminate flowered clones.

The proportion of florets set on severely pruned Fredonia vines did not differ appreciably from the proportion of florets set on less severely pruned Fredonia vines indicating that pruning decreases the set of fruit in Fredonia primarily through its effect on the pollen.

Because over-pruning is here shown to be so restrictive of grape yields and the effects of under-pruning are known to be disastrous, it is suggested that vineyardists could well afford to better control the pruning severity of Fredonia grapes.

The first year's data indicate that Concord responds to variation in pruning severity in a manner similar to that of the Fredonia variety.

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A Mineralogical Analysis of Some Pennsylvania Orchard Soils by Means of the X-Ray Spectrometer[1]

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SINCE orchards are a long-time agricultural operation, and the soil upon which they are planted largely determines their success or failure because of the soil's ability to receive, store, and liberate plant nutrients and water, research investigators have been interested in solving some of the basic causes of soil variability. The distribution and nature of the principal minerals of soils is important because many soil characteristics are based on their presence. This paper presents a study of the determination and distribution of certain essential soil minerals as they occur in some Pennsylvania orchard soils.

The essential minerals in soils are relatively few in number. Table I sets forth the distribution of the principal minerals in igneous and sedimentary materials on the surface of the earth. It will be noted that the mineral series involved are few in number and chemically are principally oxides and alumino silicates. These essential minerals are generally not chemically pure compounds, but are members of series and have variable compositions, depending upon their position in the series. This property of minerals accounts for the possibility of extreme variations in soils, even though at first sight the minerals of soils are relatively few. That these minerals are generally distributed in soils has been known for some time due to mineralogical studies carried out utilizing the general procedures of petrography. Sufficient information of a specific nature on many important soils is not available, however, due to time-consuming methods necessary to carry out such investigations. Recently, development of the X-ray spectrometer has made possible a means of acquiring such data rapidly; thus large areas may be studied in a relatively short time.

TABLE I—MINERAL COMPOSITION OF THE CRUST AND THE AVERAGE SEDIMENT OF THE EARTH

Mineral	Crust (Per Cent)	Average Sediment (Per Cent)	Average Sediment Carbonate-Free (Per Cent)
Feldspar	57.8	7.0	8.7
Quartz	12.8	38.0	47.5
Amphibole	16.0	—	—
Mica	3.6	20.0	25.0
Accessory	8.0	3.0	3.8
Clay	1.1	9.0	11.2
Carbonates	0.5	20.0	—
Limonite	0.2	3.0	3.8

The technical details of the design of the X-ray spectrometer have

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been described by Buehler (2, 3), Firth (6, 7), and Friedman (5), and will not be discussed here. The principle upon which the apparatus is designed and its operation, however, will be discussed briefly.

The principle upon which the design of the spectrometer is based is illustrated in Fig. 1. If a monochromatic divergent X-ray beam is

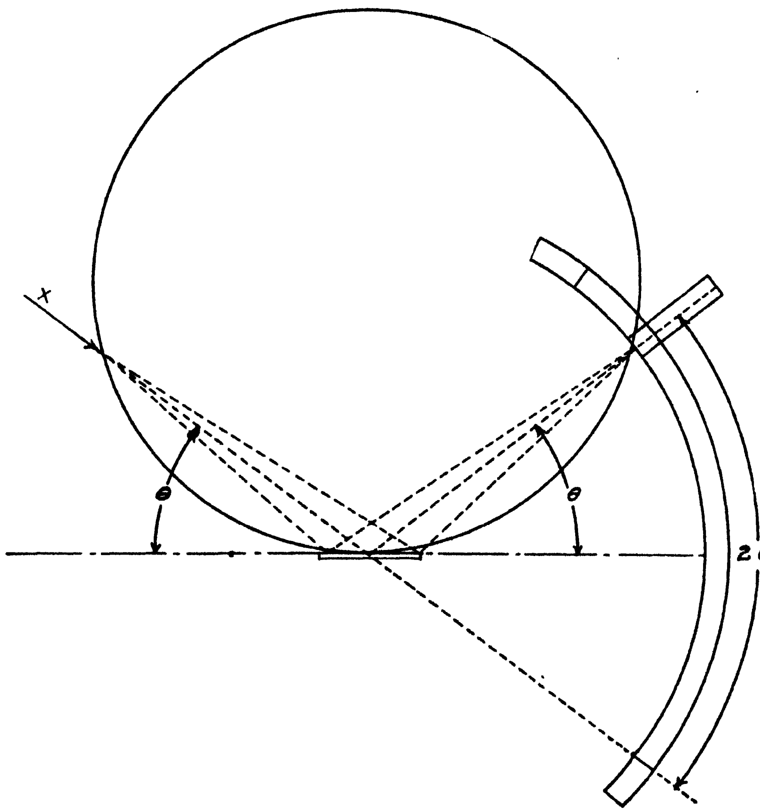

FIG. 1. Diagram illustrating the basic principle upon which the X-ray Spectrometer is designed. X is the direction of the primary X-ray beam.

projected upon a crystalline substance on the circumference of a circle, the resulting reflections occurring according to the Bragg formula are focused sharply on the circumference of the circle opposite the X-ray source. If the sample is rotated, the particular reflections characteristic of the material will therefore be focused on the circle as the particular angle equal to 2 θ is reached. A detecting device located on the arc of this circle would therefore detect these reflections one at a time as the correct angle comes into focus.

This detecting device, or analyzer, consists of a Geiger tube which may be rotated manually, or by means of a 1 rpm synchronous motor

mounted on the Geiger tube geared to the goniometer. A gearing system rotates the specimen at one-half the speed of the Geiger tube rotation, so that the angle between the specimen and the primary X-ray beam (θ) is always one-half the angle between the Geiger tube and the X-ray beam 2 θ.

The units making up the complete apparatus consist of an X-ray generator, a scanning unit, and for automatic recording of patterns, a Brown recorder. The complete unit is illustrated in Fig. 2. The X-ray

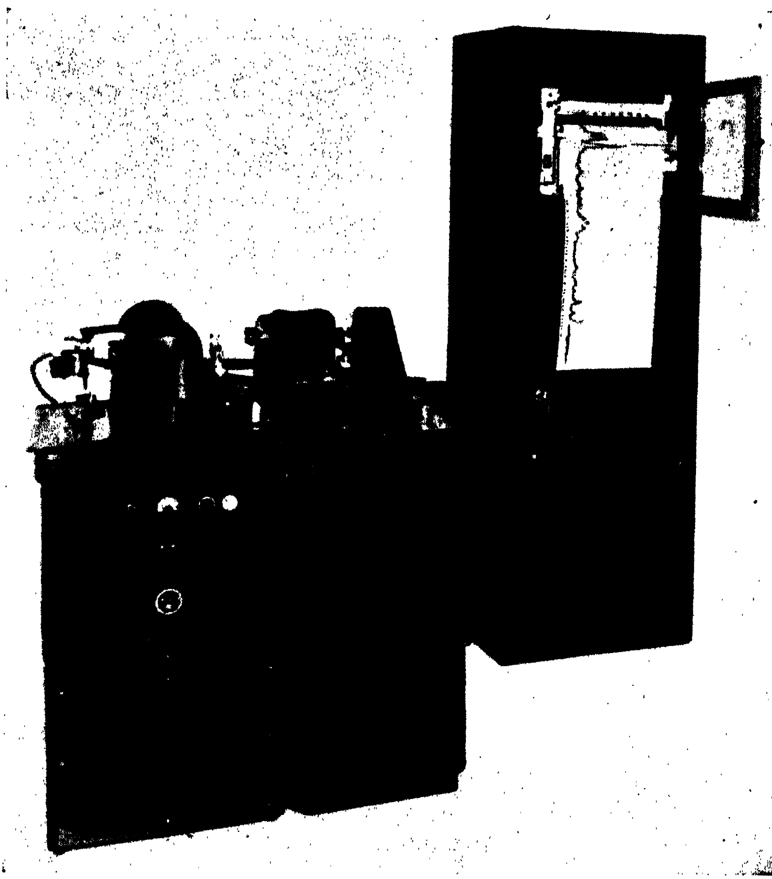

FIG. 2. The complete spectrometer, including X-ray generator, scanning unit, and Brown recorder. Courtesy of The North American Philips Company, New York.

source consists of a 35 KV air-cooled tube operated at 5.75 milliamperes. The scanning unit consists of a Geiger tube mounted on a goniometer which can be read to .01 degrees. The Geiger tube can be rotated manually, or by means of a motor. The intensities and angles

of reflections are either recorded by means of the Brown recorder, or can be read on a meter. The primary beam can be regulated by means of a slit system mounted on the X-ray tube casing and the reflected beams from the sample are received by a similar slit system in front of the window of the Geiger tube. This last slit system also includes a slot for the various filters necessary, which depends on the target material of the X-ray tube. In this particular apparatus, an X-ray tube with a copper target was used, consequently a nickel filter was necessary for the best operation. The advantages of this apparatus are that X-ray data may be determined rapidly and accurately over the whole range of reflections or only selected portions may be studied, and furthermore, a permanent record is obtained. If no recording is desired, the angles and intensities of reflection may be determined manually by means of the meter. The use of this apparatus results, therefore, in a record on calibrated paper of the various X-ray reflections of crystalline compounds instead of the photographic record of film techniques. The d values may be readily computed using Bragg's formula, remembering that the angles read on the goniometer are 2θ and that the target of the X-ray tube is copper.

The samples for study are mounted on glass microscope slides using about .15 grams of a sample and a few drops of a mixture of amyl acetate and collodion spread out as a film on the slide, allowed to dry, and trimmed to the proper size for the specimen holder by means of a razor blade. In the case of the soils studied, iron was removed by the nascent hydrogen method, using magnesium ribbon and a potassium oxalate-oxalic acid buffer solution as has been described (8). This is necessary in order that clean mineral separates be secured, and also to eliminate fluorescent effects on radiation due to iron compounds. After the removal of iron from the soils, mechanical analysis was carried out and the very fine sand, silt and clay fractions studied by means of the spectrometer.

The interpretation of the diffraction patterns may be undertaken in two ways. The d values may be computed and reference made to the standard tables of the American Society for Testing Materials, or comparisons may be made with patterns prepared using standard minerals. The last method is desirable for rapid comparison as one can see at a glance the predominating minerals. It is useful, however, for detailed work, to compute d values in addition because in this manner lines of minerals which occur in small quantities are detected.

Table II sets forth a comparison of the d values for some standards as recorded in the American Society for Testing Materials table (1) and the values obtained by means of the X-ray spectrometer. It will be noted that the comparison of the d values with the standards is excellent with the exception of certain of the clay minerals, but their identification can be effected readily because of their outstanding differences. Figs. 3 and 4 illustrate the type of pattern obtained for the standard minerals which are common to soils. The intensities of the lines of the patterns determined by means of the spectrometer are indicative of the abundance of the particular minerals determined qualitatively. The determination of the quantitative distribution of the par-

TABLE II—COMPARISON OF D VALUES IN ANGSTROM UNITS OBTAINED BY SPECTROMETER WITH THE STANDARD VALUES OF THE AMERICAN SOCIETY FOR TESTING MATERIALS*

Mineral																		
Quartz, A.S.T.M.	4.25	3.35	2.45	2.29	2.23	2.12	1.97	1.82	—	—	—	—	—	—	—	—	—	—
Spectrometer	4.25	3.34	2.45	2.27	2.23	2.12	1.98	—	—	—	—	—	—	—	—	—	—	—
Albite A.S.T.M.	6.40	4.05	3.80	3.66	3.20	2.96	2.65	2.56	2.44	—	—	—	—	—	—	—	—	—
Spectrometer	6.40	4.05	3.79	3.68	3.20	2.97	2.65	2.56	2.45	—	—	—	—	—	—	—	—	—
Microcline A.S.T.M.	4.24	4.01	3.85	3.69	3.49	3.35	3.25	3.03	2.94	2.88	2.76	2.61	2.52	2.43	2.33	—	—	—
Spectrometer	4.24	4.01	3.84	3.71	3.47	3.37	3.25	3.03	2.95	2.91	2.78	2.63	2.57	2.44	2.28	—	—	—
Muscovite A.S.T.M.	9.90	5.00	4.47	3.88	3.72	3.49	3.33	3.19	2.99	2.86	2.79	2.56	2.47	2.38	2.28	2.21	2.13	1.99
Spectrometer	9.90	5.01	4.47	3.89	3.73	3.50	3.32	3.21	3.01	—	2.79	2.56	2.50	2.42	—	—	—	2.00
Kaolin A.S.T.M.	7.20	4.45	4.30	4.20	4.04	3.59	2.56	2.50	2.34	2.00	—	—	—	—	—	—	—	—
Spectrometer	7.21	4.45	4.35	4.18	—	3.58	2.57	2.50	2.35	2.00	—	—	—	—	—	—	—	—
Illite A.S.T.M.	10.00	—	—	4.46	—	—	—	2.56	—	—	—	—	—	—	—	—	—	—
Spectrometer	10.89	7.29	5.08	4.54	4.30	3.40	3.39	2.60	—	—	—	—	—	—	—	—	—	—
Montmorillonite A.S.T.M.	15.00	4.45	—	1.49	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Spectrometer	15.74	4.50	2.50	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

*American Society for Testing Materials Philadelphia, Pa. August, 1945.

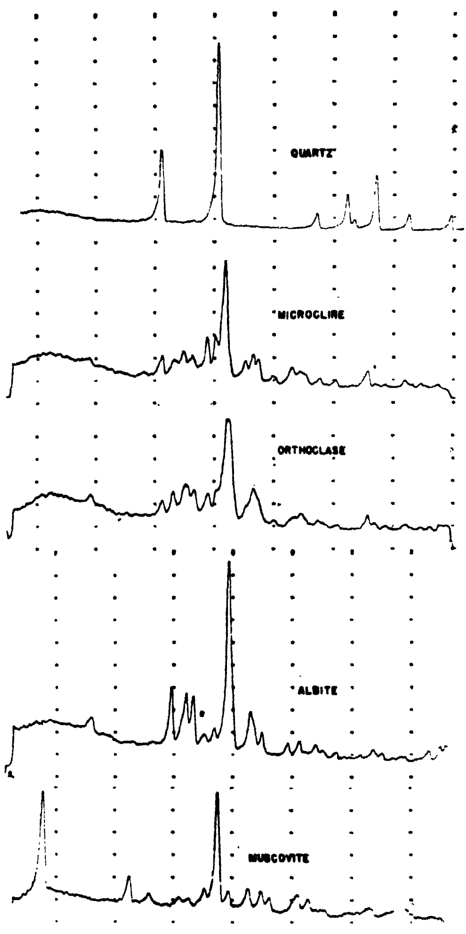

FIG. 3. Standard patterns for quartz, microcline, orthoclase, albite and muscovite. N.B.—In this and all following patterns, the figures at the bottom refer to angular readings on the goniometer.

ticular minerals detected cannot be made by direct comparison with standard minerals. Work at this Station indicates that it is possible to determine quantitatively the principal minerals in soils by means of the X-ray spectrometer. The intensities of the reflections recorded are not proportional to the weight distribution, but to their volumes. In other words, it is necessary to determine the percentage by volume of the minerals first, and convert to per cent by weight if it is so desired. This was found in the study of the quantitative distribution of minerals using an internal standard such as ammonium chloride and will be the subject of a later paper.

As stated previously, the soil fractions studied were the very fine sand, silt and clay separates, as it has been found that it is in these fractions that the outstanding mineral characteristics occur. Soil analyses presented are of the Chester-Manor, Duffield and Mont Alto series of Pennsylvania.

Fig. 5 is a pattern of the very fine sand fraction of Chester-Manor soil compared with the standard pattern for quartz and muscovite. It is not difficult to observe that the outstanding essential minerals of this particular soil are quartz and muscovite, with small amounts of other minerals.

Figs. 6 and 7 are a similar comparison for the Duffield soil, only in the first case the essential minerals are quartz and microcline while a similar comparison of the very fine sand separate of the Mont Alto soil (Fig. 7) shows that the essential minerals are quartz and albite.

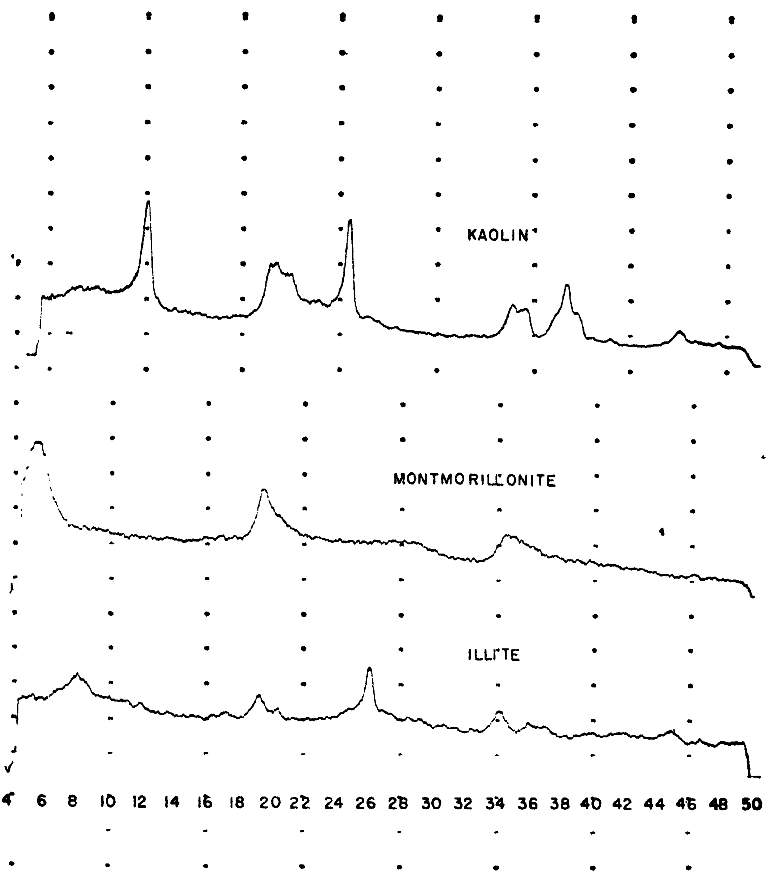

FIG. 4. Standard patterns for kaolin, montmorillonite, and illite.

Fig. 8 is a comparison of the very fine sand separate of these three soils from which it can be seen that they are extremely different in respect to their essential mineral content.

The above methods of comparison illustrate the manner in which the gross mineral composition of soils may be determined in a routine fashion. It will be noted that the patterns were recorded from 50 degrees to about 5 degrees on the goniometer. This was because preliminary studies showed that the principal lines of the various minerals indicated were not sufficiently abundant over the whole range (90 degrees) for identification purposes to warrant the time spent to make the determination over the whole goniometer range. The time required to make a recording from 50 degrees to 5 degrees is 45 minutes, and a decided saving in time is thus affected in determining the general mineral composition of soil separates. For very rapid comparisons, probably less arc could be used than 45 degrees.

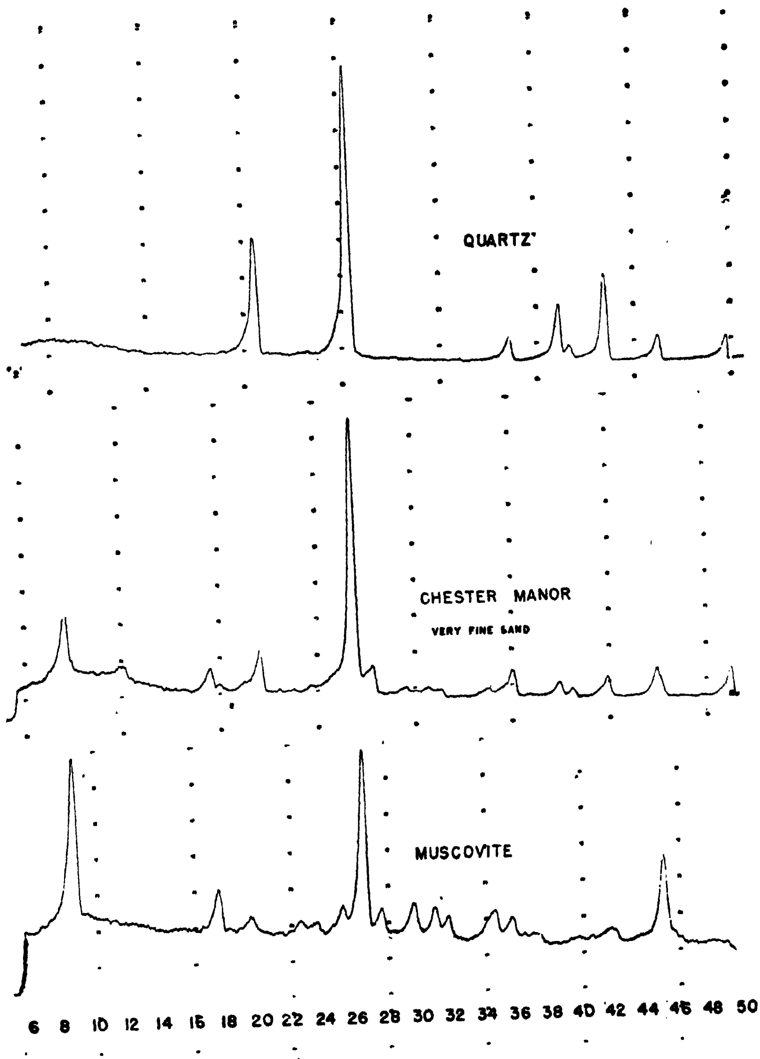

FIG. 5. Comparison of pattern of the very fine sand separate of the Chester-Manor soil with quartz and muscovite standards.

The study of the variations of the mineral composition of the very fine sand, silt and clay fractions in a particular soil are of extreme interest and importance. The processes of weathering may be followed with the reduction in particle size, and some characteristics have been noted in comparisons of the mineral compositions of soils which have not received the attention they should.

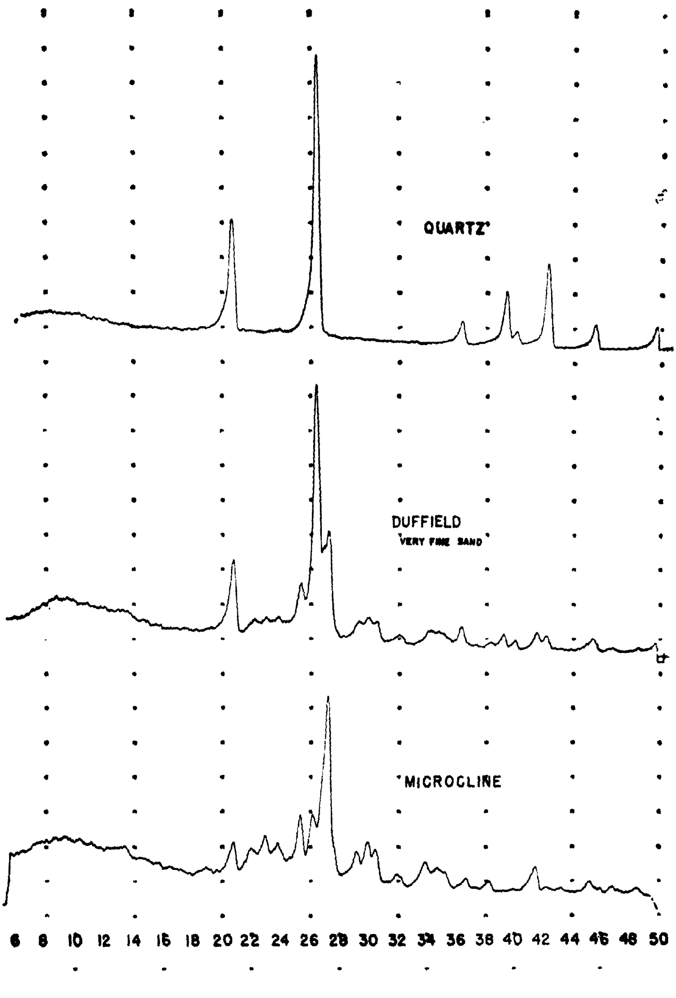

FIG. 6. Comparison of pattern of the very fine sand separate of the Duffield soil with quartz and microcline standards.

Fig. 9 is a comparison of the mineral compositions of the very fine sand, silt and clay separates of the Chester-Manor soil, as previously noted, the predominating minerals in the very fine sand fraction being quartz and muscovite. In addition, however, indications of the presence of a mineral of the kaolin group was noted in the very fine sand. The presence of this particular mineral, which is the product of weathering,

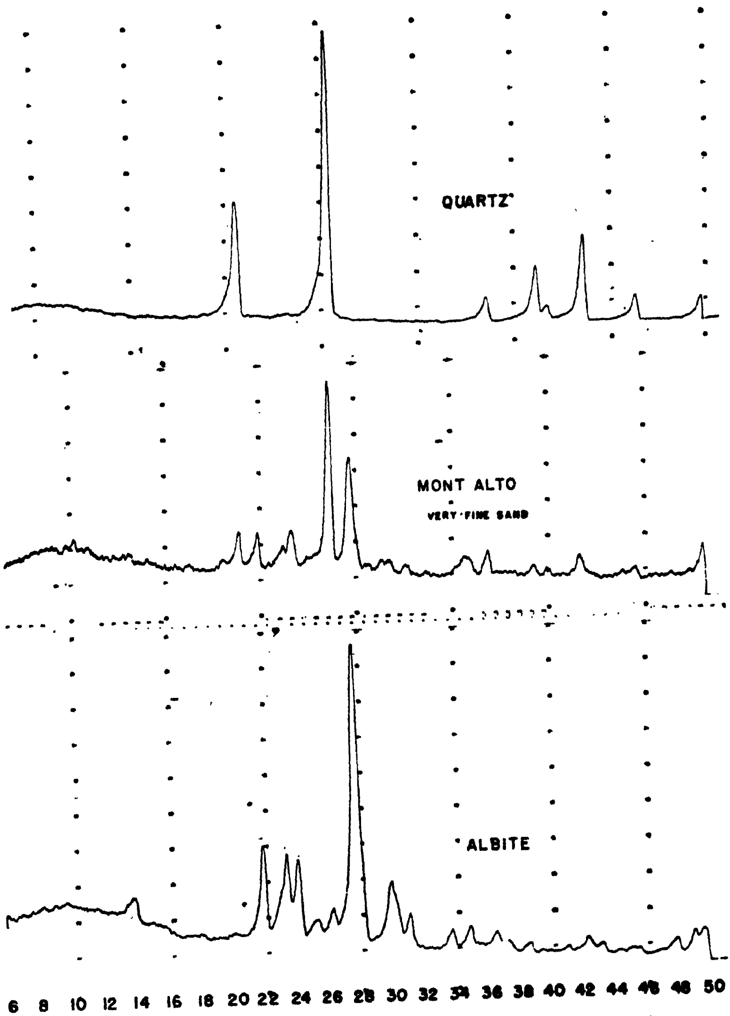

FIG. 7. Comparison of pattern of the very fine sand separate of the Mont Alto soil with quartz and albite sands.

in the very fine sand fraction is quite interesting, and the fact that in the silt fraction it is very predominating and does not appear in the clay fraction is worthy of study. The presence of clay minerals has always been assumed to occur chiefly in the silt and clay fractions but in this particular instance we observe a clay mineral not only in the silt and clay fractions but in the very fine sand separate as well. The predominating mineral in the clay fraction is chiefly illite. Illite has been observed in many soils and is a very important mineral from the

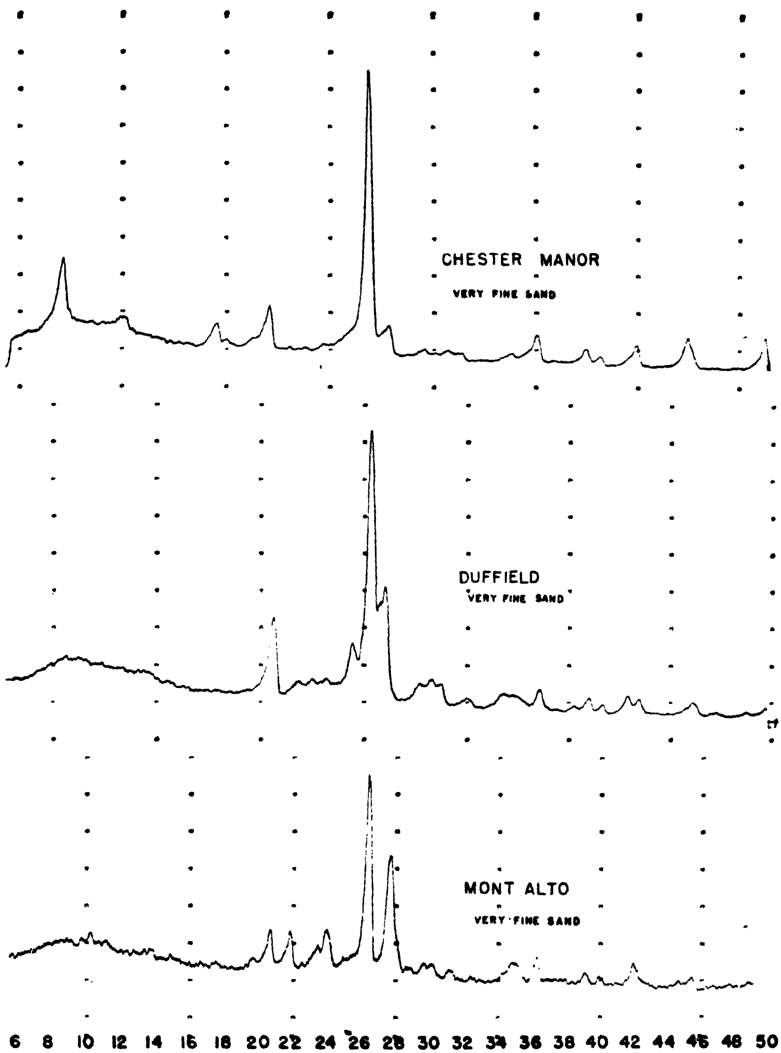

FIG. 8. Patterns of the very fine sand separates of the Duffield, Chester-Manor and Mont Alto soils illustrating differences in essential mineral composition.

standpoint of the fixation and release of certain plant nutrients, principally potassium. This soil is of decided interest because it illustrates the fact that in the process of weathering there are no sharp dividing lines between the primary and the secondary minerals. Rather, there are series of intermediate clay compounds which are not well understood, the study of which should lead to very interesting information.

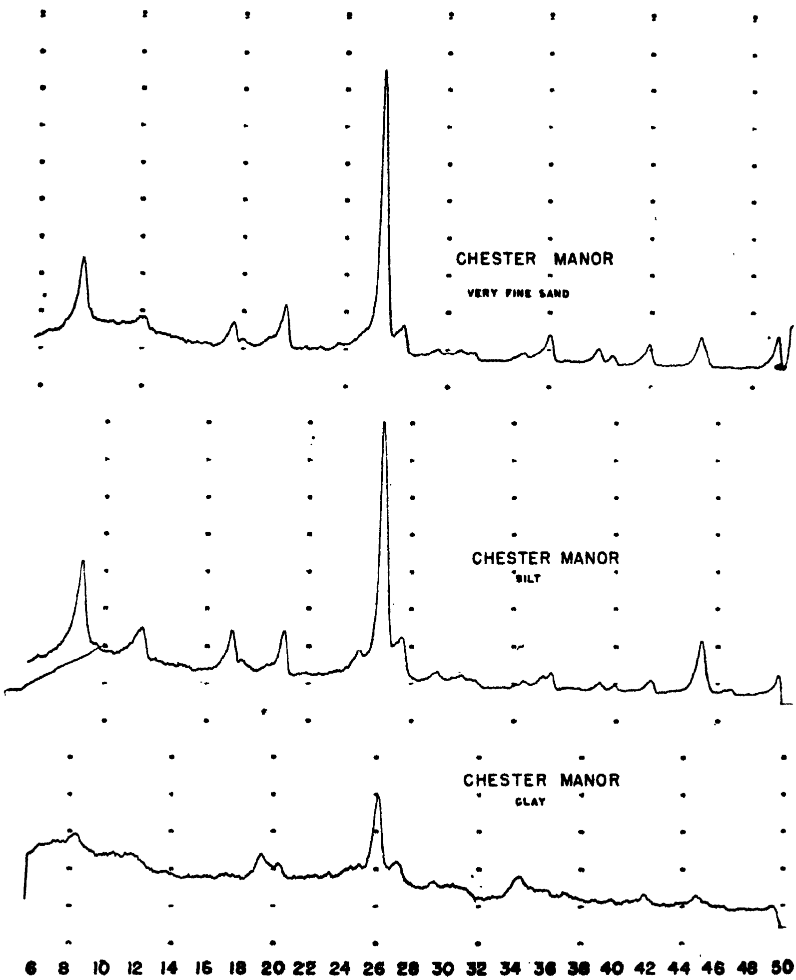

FIG. 9. Patterns of the very fine sand, silt and clay separates of the Chester-Manor soil.

Fig. 10 is a similar comparison of the very fine sand, silt and clay fractions of the Duffield soil. Here the principal minerals in the very fine sand fraction are quartz and microcline, and a closer study of the d values computed from the angular readings reveal the presence of minor amounts of muscovite. Study of the silt fractions show that the same minerals occur in this separate as in the very fine sands, but in addition, very distinct lines for muscovite and kaolin appear. The pattern for the clay separate contains distinct lines of quartz and microcline. However, in addition to these, very distinct lines of hydrous mica are present and the kaolin of the silt separate is not apparent.

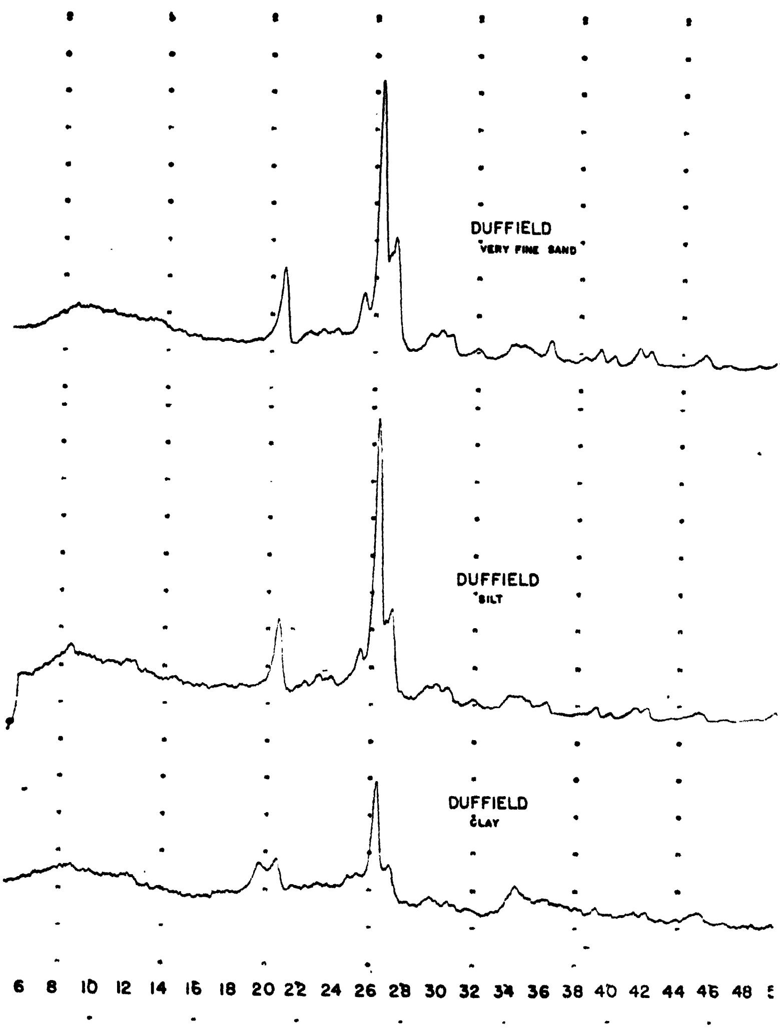

FIG. 10. Patterns of the very fine sand, silt and clay separates of the Duffield soil.

Fig. 11 is a similar comparison of the separates of the Mont Alto soil. The chief minerals in the very fine sands consist of quartz and albite with minor amounts of muscovite and kaolin. There is little difference between the very fine sand and silt fraction. This is probably due to the decided resistance of the quartz and albite to weathering. The clay fraction contains some quartz and no albite, but is principally hydrous mica or illite, and the kaolin lines are not present.

A comparison of the X-ray diffraction patterns as determined by the X-ray spectrometer of the three soils indicated shows that one can

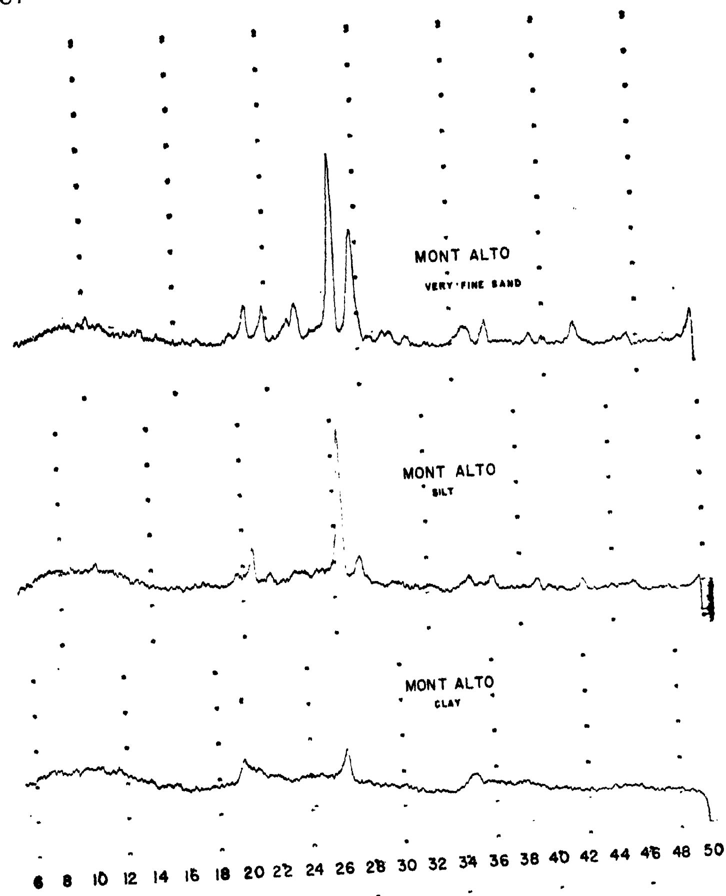

FIG. 11. Patterns of the very fine sand, silt and clay separates of the Mont Alto soil.

expect wide differences in the essential mineral composition of soils. In general, the characteristics of the very fine sand and silt fractions in the same soil appear to be about the same, but under certain conditions minerals of the kaolin group appear as a decomposition product of the feldspar and muscovite which form the dominant mineral other than quartz. It is interesting to note that this kaolin is not present in appreciable amounts in the clay fraction, but appears in the silt and in some cases in the very fine sand fraction. This suggests the formation of intermediate clay minerals in the course of weathering. These may be present as coatings on the outside of particles of primary minerals and as such may play an important part in soil reactions. Intermediate clay compounds being more or less unstable may have much to do with the fixation and release of plant nutrients. Knowing where such

conditions exist is of interest in studying such soil characteristics. The Chester Manor soil in which these intermediate clay compounds appear most extensively is a soil which is used in the southeastern part of Pennsylvania for orchards and has presented many difficulties, particularly having to do with the fixation and release of potash (4). From the standpoint of the formation of intermediate clay compounds it is a rather extreme case. However, traces of these particular weathering products may be detected in most soils. It is such information when correlated with field and laboratory studies on the reaction of soils to various mineral nutrients which would give us a very valuable insight into the long-time requirements necessary for maintaining a soil in a high state of fertility. The maintenance of certain levels of mineral nutrients can be varied, depending upon the essential mineral characteristics of the soil concerned. That all soils will not react the same is, of course, well known, but the reasons for these reactions are not understood and will not be understood until we use the mineral composition of the soil as a basis for interpretation of our results.

Summary

The above discussion consists of a preliminary report on the use and operation of the X-ray spectrometer as a means of determining the essential minerals of soils. The principle upon which the X-ray spectrometer is designed, and the essential features of the apparatus are briefly described. Diffraction patterns of standard minerals are presented and are compared with the standard data of the American Society for Testing Materials. The agreement is excellent, but the need for more and better standards, particularly for the clay minerals, is indicated.

Diffraction patterns for the very fine sand, silt and clay separates of the Chester Manor, Duffield and Mont Alto soil series of Pennsylvania, soils which are used primarily in orchards, are used as examples of the variability of the mineral composition of soils. Details of the weathering of some of the primary minerals of soils are pointed out, the presence of minerals of the kaolin group in the very fine sand and silt fractions being noticeable and the lack of this mineral in the clay fractions being most interesting. The clay fractions in all the soils discussed consist essentially of hydrous mica with some primary minerals. The presence of intermediate clay minerals formed in the course of weathering processes is suggested as an interesting phase of soil study. The exact part which these intermediate clay minerals play in soil reactions is not understood or appreciated, principally because of the difficulty in determining where such materials occur in amounts sufficient for study. It is doubtful if they are entirely absent from any soil, but where certain primary minerals, particularly muscovite, occur in the coarse fractions, these compounds seem to occur in fairly large quantities in the silt fractions. Detailed study of the essential mineral characteristics of soils in relation to fertilizer and moisture relationships should be of definite value in the planning of agricultural operations that are to be of long duration, particularly the establishing of orchards.

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Comparative Value of Nine Rootstocks for Ten Vinifera Grape Varieties

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The fruit production and vigor of vinifera grape varieties growing on their own roots is often decreased by root injury caused by the grape phylloxera (*Phylloxera vitifoliae* (Fitch)) and the rootknot nematode (*Heterodera maroni* (Cornu) Goodey). Grape rootstocks have been used to overcome the loss caused by these two injurious pests of vinifera grape vines. Certain rootstocks have been known to give more satisfactory results than others (1). To obtain additional information on the comparative value of rootstocks for vinifera grape varieties, a test plot consisting of nine selected rootstocks grafted with 10 vinifera grape varieties was started at the United States Horticultural Field Station, Fresno, California, in the spring of 1932.

The rootstock vines, 1-year-old, were planted 8 feet apart in rows 12 feet apart. The plot, consisting of 24 rows of 50 vines each was completely surrounded with a buffer row of vines. There were two rows of each of eight rootstocks and eight rows of the ninth. Each third row in the test plot was planted with the rootstock, Solonis x Othello, No. 1613, so that it adjoined each of the other rootstocks and was used as a standard of comparison. The rootstocks were bud-grafted (3) with 10 vinifera varieties in the fall of 1932, so that there were two lots of five vines on each of eight rootstocks and eight lots of five vines on the ninth rootstock, Solonis x Othello, No. 1613.

The rootstocks selected were Berlandieri x Riparia, No. 420–A; Chasselas x Berlandieri, No. 41–B; Constantia; Dog Ridge; Monticola x Riparia, No. 18815; Mourvedre x Rupestris, No. 1202; Riparia x Rupestris, No. 3309; Rupestris St. George; and Solonis x Othello, No. 1613. These rootstocks were selected from many which in previous tests (1) grew well under different soil and climatic conditions and had sufficient resistance to phylloxera. Later tests (2) have indicated that some of the stocks selected were more susceptible to rootknot nematode than others. The rootstock, Solonis x Othello, No. 1613, is the main rootstock now in commercial use in the San Joaquin Valley in California and was for this reason selected as the standard of comparison. It was introduced from France by the United States Department of Agriculture and planted in the experimental vineyards in 1903. Previously reported tests (2) have indicated that it is one of the better rootstocks for resistance to rootknot nematode.

The vinifera varieties selected were Alexandria (Muscat), Malaga, Flame Tokay, Alphonse Lavallee (Ribier), Emperor, Sultanina (Thompson Seedless), Ohanez (Almeria), Castiza (Red Malaga), Black Monukka, and Corinthe noir (Zante Currant). The plot was bud-grafted by two men grafting crosswise of the stock rows so that each man grafted an equal number of the vinifera vines on each rootstock to equalize differences due to individual grafters.

Records were obtained on the percentage stand of rootstock varieties the first year of planting; the weight of top growth the first season:

the percentage of successful grafts of vinifera varieties; the increase in stock size over the first four years; and individual vine, fruit, and wood weights (brush pruned off at pruning time), each year after full production, extending from 1937 to 1945 inclusive.

The stock planting at the end of the first season showed a 99.6 per cent stand, with five vines missing out of 1200 planted. Four of these missing vines occurred in the Chasselas x Berlandieri, No. 41–B rows and one in the Rupestris St. George row. Missing vines were replanted. The percentage stand indicates that nearly a perfect stand can be obtained when rooted vines are used, irrespective of the rootstock variety.

At the beginning of the second season's growth, when all stocks were pruned off above the vinifera bud-graft, the weight of the first season's growth was obtained. Since brush weights were relatively small the first season, they were recorded in grams per vine. In the strong group of stocks, ranging from 300 to 350 grams of brush per vine, were Solonis x Othello, No. 1613; Mourvedre x Rupestris, No. 1202; and Constantia. In the medium group, ranging from 200 to 250 grams per vine, were Dog Ridge; Rupestris St. George; and Monticola x Riparia, No. 18815. In the weak group, ranging from 100 to 180 grams per vine, were Berlandieri x Riparia, No. 420–A; Chasselas x Berlandieri, No. 41–B; and Riparia x Rupestris, No. 3309. While growth the first season does not necessarily give the true vigor of rootstocks, it does indicate the trend toward the strong, medium, and weak stocks.

The vinifera varieties did not show any difference in the ease of grafting on the different rootstocks. An over-all stand of 96.6 per cent was obtained for all varieties on all rootstocks. The following stands were obtained on the several rootstock varieties: Berlandieri x Riparia, No. 420–A, 99 per cent; Chasselas x Berlandieri, No. 41–B, 98 per cent; Constantia, 98 per cent; Dog Ridge, 98 per cent; Monticola x Riparia, No. 18815, 100 per cent; Mourvedre x Rupestris, No. 1202, 86 per cent; Riparia x Rupestris, No. 3309, 99 per cent; Rupestris St. George, 92 per cent; and Solonis x Othello, No. 1613, 97 per cent. The lower percentage of Mourvedre x Rupestris, No. 1202 was mainly due to a 40 per cent stand of Ohanez grafts in one replicate of five vines while the other replicates gave an 80 per cent stand. Since in other tests (1) Ohanez has been growing on Mourvedre x Rupestris, No. 1202 for 30 years, the reduced percentage here would appear to be a mechanical defect in the grafting operation rather than a lack of affinity of Ohanez for this particular stock.

The increase in stock size was obtained by comparing measurements made at the time of planting in 1932 with measurements made in 1936. After 4 years differences were apparent in the trunk size of the different rootstocks. Solonis x Othello, No. 1613, Constantia, Rupestris St. George, and Mourvedre x Rupestris, No. 1202 gave increases in trunk circumference ranging from 12.50 to 11.75 centimeters; Dog Ridge, Berlandieri x Riparia, No. 420–A, and Chasselas x Berlandieri, No. 41–B, from 11.5 to 11.0 centimeters; Monticola x Riparia, No. 18815 and Riparia x Rupestris, No. 3309, from 10.0 to 9.5 centi-

meters. The stocks grafted with the more vigorous varieties had larger stock increases than the same stocks grafted with weaker varieties.

The average increase in rootstock circumference of all stocks under Emperor, Black Monukka, Ohanez, Sultanina, and Malaga ranged from 12.0 to 12.4 centimeters; under Flame Tokay and Ribier, 11.0 to 11.8 centimeters; and under Alexandria, Castiza, and Corinthe Noir, 10.0 to 10.5 centimeters. Either a vigorous scion variety tended to promote greater stock size increase or the weaker scion variety tended to retard stock growth, or possibly both effects were present. The increase in size to some extent indicated the value of the stock since it was noted that where the stock size was considerably smaller than the scion variety, scion roots had a greater tendency to grow. The removal of these scion roots necessitated additional labor, and where they were not removed the stock was weakened. The stocks in order of their increase in size over the 4-year period, from largest to smallest, were Solonis x Othello, No. 1613; Constantia; Rupestris St. George; Mourvedre x Rupestris, No. 1202; Dog Ridge; Berlandieri x Riparia, No. 420–A; Chasselas x Berlandieri, No. 41–B; Monticola x Riparia, No. 18815, and Riparia x Rupestris, No. 3309.

The fruit and wood (pruning brush) weights per vine were taken from 1937 to 1945 inclusive. To tabulate all these individual records would necessitate considerable space. Therefore only a summary of these records is presented in Table I. The rootstock varieties are tabulated in the order in which the rows occurred in the test planting. Column 1 gives the rootstock varieties, column 2 the average yearly fruit production per vine for the 9 years, with the probable error of the mean, column 3 indicates the difference from the standard of comparison divided by the probable error of the difference, column 4 the yearly average wood weight per vine with the probable error of the mean, and column 5 the difference from the standard of comparison divided by the probable error of the difference.

The interpretation of the fruit and wood weight records has been based on the records of the fruiting varieties on each rootstock compared with the rootstock, Solonis x Othello, No. 1613, which was used as a standard. Since this standard stock adjoined each rootstock row in the planting and since there were two replicate lots of five vines each fruiting variety, the effects of soil differences were minimized. In evaluating a rootstock, the fruit weight, indicating production, and the wood weight, indicating vigor, should be taken into consideration.

In Table I the fruiting varieties are tabulated in order of their location in the test planting. The comparative value of the rootstocks for each fruiting variety are discussed in the following paragraphs.

Alexandria:—The preponderance of minus signs in the D/PE columns for both fruit and wood weights of this variety can be noted. The rootstock Monticola x Riparia, No. 18815 gave a plus sign for both fruit and wood weights but only in minor amounts. Dog Ridge gave a plus sign for wood weight which was counterbalanced by decreased fruit yield. The stocks Chasselas x Berlandieri, No. 41–B, Rupestris St. George, Constantia, and Riparia x Rupestris, No. 3309 were the low-rating stocks for Alexandria. While the majority of these com-

TABLE I—Comparative Nine-Year Averages of Fruit and Wood Weights (Pounds Per Vine) of Vinifera Grape Varieties Grafted on Different Rootstocks, Using Solonis x Othello, No. 1613 as a Standard (1937–1945)

Rootstock Variety	Fruit Weights	D/PE*	Wood Weights	D/PE*
	Alexandria			
Mourvedre ×Rupestris, No. 1202	24.2 ±1.27	−0.71	3.7 ±0.33	−0.25
Solonis ×Othello, No. 1613	25.7 ±1.73	——	4.6 ±0.22	——
Berlandieri ×Riparia, No. 420-A	24.1 ±0.67	−0.87	4.2 ±0.64	−0.71
Chasselas ×Berlandieri, No. 41-B	23.3 ±0.78	−1.32	3.8 ±0.11	−3.61
Solonis ×Othello, No. 1613	25.1 ±1.13	——	4.8 ±0.32	——
Constantia	22.3 ±2.95	−0.89	3.1 ±0.67	−2.19
Rupestris St. George	20.0 ±0.94	−3.85	4.3 ±0.10	−1.23
Solonis ×Othello, No. 1613	25.0 ±0.92	——	4.6 ±0.25	——
Monticola ×Riparia, No. 18815	25.6 ±1.05	+0.44	5.2 ±0.19	+1.81
Riparia ×Rupestris, No. 3309	24.9 ±0.74	−2.22	4.7 ±0.24	−0.31
Solonis ×Othello, No. 1613	28.3 ±1.35	——	4.8 ±0.26	——
Dog Ridge	22.5 ±1.78	−2.59	5.6 ±0.33	+1.93
	Malaga			
Mourvedre ×Rupestris, No. 1202	35.7 ±2.07	0.00	8.7 ±0.59	−1.30
Solonis ×Othello, No. 1613	35.7 ±2.18	——	9.7 ±0.51	——
Berlandieri ×Riparia, No. 420-A	45.7 ±2.42	+3.10	8.1 ±0.38	−2.54
Chasselas ×Berlandieri, No. 41-B	36.9 ±1.85	+0.03	5.5 ±0.28	−5.47
Solonis ×Othello, No. 1613	36.8 ±2.62	——	8.4 ±0.45	——
Constantia	39.2 ±1.39	+0.81	9.2 ±0.51	+1.17
Rupestris St. George	40.6 ±1.02	−1.67	7.3 ±0.30	−1.85
Solonis ×Othello, No. 1613	44.0 ±1.75	——	8.3 ±0.45	——
Monticola ×Riparia, No. 18815	50.4 ±1.68	+2.67	7.7 ±0.24	−1.18
Riparia ×Rupestris, No. 3309	42.9 ±3.70	+0.18	8.3 ±0.56	−1.73
Solonis ×Othello, No. 1613	42.1 ±2.23	——	9.6 ±0.51	——
Dog Ridge	39.9 ±2.05	−0.72	10.3 ±0.28	+1.21
	Flame Tokay			
Mourvedre ×Rupestris, No. 1202	44.0 ±1.54	+1.16	8.1 ±0.67	+1.05
Solonis ×Othello, No. 1613	41.0 ±2.10	——	7.3 ±0.41	——
Berlandieri ×Riparia, No. 420-A	41.2 ±1.87	+0.07	5.8 ±0.46	−2.34
Chasselas ×Berlandieri, No. 41-B	40.1 ±2.12	−0.49	4.9 ±0.32	−2.94
Solonis ×Othello, No. 1613	41.4 ±1.60	——	6.3 ±0.33	——
Constantia	41.4 ±1.57	0.00	8.0 ±0.29	+3.95
Rupestris St. George	38.9 ±1.75	−4.37	5.6 ±0.34	−4.10
Solonis ×Othello, No. 1613	47.7 ±1.00	——	7.2 ±0.21	——
Monticola ×Riparia, No. 18815	47.5 ±0.81	−0.16	6.9 ±0.25	−0.97
Riparia ×Rupestris, No. 3309	42.1 ±0.84	−2.38	6.6 ±0.31	−2.91
Solonis ×Othello, No. 1613	47.3 ±2.02	——	7.9 ±0.35	——
Dog Ridge	31.1 ±0.67	−7.64	8.0 ±0.24	+0.27
	Alphones Lavallee (Ribier)			
Mourvedre ×Rupestris, No. 1202	35.6 ±3.12	−0.45	6.8 ±0.54	−0.53
Solonis ×Othello, No. 1613	37.6 ±3.21	——	7.3 ±0.66	——
Berlandieri ×Riparia, No. 420-A	36.0 ±2.48	−0.40	7.7 ±0.58	+0.51
Chasselas ×Berlandieri, No. 41-B	36.9 ±2.41	+1.83	6.0 ±0.50	−1.22
Solonis ×Othello, No. 1613	31.1 ±2.28	——	6.8 ±0.48	——
Constantia	29.7 ±2.08	−0.45	4.4 ±0.45	−3.66
Rupestris St. George	28.8 ±1.69	−1.80	6.8 ±0.55	+0.07
Solonis ×Othello, No. 1613	35.4 ±3.25	——	6.7 ±0.61	——
Monticola ×Riparia, No. 18815	36.9 ±2.73	+0.35	6.0 ±0.70	−0.74
Riparia ×Rupestris, No. 3309	33.2 ±1.60	+0.11	8.0 ±0.41	+0.41
Solonis ×Othello, No. 1613	32.9 ±2.32	——	7.7 ±0.68	——
Dog Ridge	22.4 ±1.16	−4.05	7.1 ±0.54	−0.69
	Emperor			
Mourvedre ×Rupestris, No. 1202	36.0 ±2.20	+1.75	9.2 ±0.57	+0.15
Solonis ×Othello, No. 1613	31.1 ±1.72	——	9.1 ±0.67	——
Berlandieri ×Riparia, No. 420-A	33.0 ±1.15	+0.92	6.8 ±0.25	−3.27
Chasselas ×Berlandieri, No. 41-B	31.0 ±1.39	+0.66	5.6 ±0.32	−4.36
Solonis ×Othello, No. 1613	29.6 ±1.61	——	7.8 ±0.38	——
Constantia	33.0 ±1.72	+1.45	8.7 ±0.43	+1.45
Rupestris St. George	29.6 ±1.41	−0.83	6.6 ±0.27	−3.48
Solonis ×Othello, No. 1613	31.6 ±1.97	——	8.3 ±0.40	——
Monticola ×Riparia, No. 18815	37.1 ±2.26	+1.83	7.6 ±0.43	−1.15
Riparia ×Rupestris, No. 3309	34.4 ±2.21	+1.37	7.9 ±0.51	−0.10
Solonis ×Othello, No. 1613	30.4 ±1.91	——	8.0 ±0.31	——
Dog Ridge	26.2 ±1.81	−1.60	9.6 ±0.53	+2.50

*Difference from the standard of comparison, Solonis ×Othello, No. 1613, in terms of probable error. Differences are not to be considered significant unless they are at least three times the probable error, which means that the odds against such differences occurring under uniform conditions are 22 to 1.

TABLE I—*Concluded*

Rootstock Variety	Fruit Weights	D/PE*	Wood Weights	D/PE*
	Sultanina			
Mourvedre ×Rupestris, No. 1202	45.9 ±2.23	−1.64	11.0 ±1.08	−0.74
Solonis ×Othello, No. 1613	52.2 ±3.12	—	12.1 ±1.05	—
Berlandieri ×Riparia, No. 420-A	52.0 ±3.46	−0.04	12.1 ±1.35	0.00
Chasselas ×Berlandieri, No. 41-B	48.3 ±2.74	−0.84	8.5 ±0.65	−1.25
Solonis ×Othello, No. 1613	51.6 ±2.82	—	10.0 ±1.00	—
Constantia	43.4 ±1.38	−2.62	11.3 ±0.92	+0.98
Rupestris St. George	35.8 ±1.48	−8.44	7.4 ±0.42	−3.28
Solonis ×Othello, No. 1613	53.1 ±1.43	—	9.4 ±0.45	—
Monticola ×Riparia, No. 18815	41.4 ±1.88	−4.98	7.2 ±0.36	−3.79
Riparia ×Rupestris, No. 3309	42.2 ±2.50	−1.74	6.0 ±1.05	−4.67
Solonis ×Othello, No. 1613	47.7 ±1.94	—	11.6 ±0.59	—
Dog Ridge	35.6 ±1.40	−5.01	9.9 ±0.75	−1.79
	Ohanez			
Mourvedre ×Rupestris, No. 1202	—	—	—	—
Solonis ×Othello, No. 1613	51.8 ±2.28	—	12.7 ±0.50	—
Berlandieri ×Riparia, No. 420-A	56.3 ±1.89	+1.52	9.0 ±0.18	−6.90
Chasselas ×Berlandieri, No. 41-B	58.2 ±1.18	+1.03	6.0 ±0.22	−8.48
Solonis ×Othello, No. 1613	56.5 ±1.18	—	11.0 ±0.55	—
Constantia	55.7 ±2.51	−0.29	10.3 ±0.49	−0.96
Rupestris St. George	46.8 ±2.04	−0.95	7.3 ±0.46	−4.76
Solonis ×Othello, No. 1613	49.6 ±2.04	—	11.4 ±0.73	—
Monticola ×Riparia, No. 18815	43.9 ±1.36	−2.32	9.2 ±0.46	−2.56
Riparia ×Rupestris, No. 3309	41.8 ±3.67	−0.42	6.2 ±1.05	−3.78
Solonis ×Othello, No. 1613	43.8 ±2.96	—	10.7 ±1.57	—
Dog Ridge	53.9 ±2.27	+2.71	6.7 ±0.22	−5.96
	Castiza			
Mourvedre ×Rupestris, No. 1202	43.4 ±2.98	−1.80	6.5 ±0.55	−3.22
Solonis ×Othello, No. 1613	52.0 ±3.73	—	8.5 ±0.30	—
Berlandieri ×Riparia, No. 420-A	63.2 ±3.80	+2.10	6.9 ±0.43	−3.08
Chasselas ×Berlandieri, No. 41-B	63.4 ±3.37	+1.96	5.3 ±0.43	−4.00
Solonis ×Othello, No. 1613	52.6 ±4.36	—	7.9 ±0.48	—
Constantia	34.8 ±3.55	−3.17	8.4 ±0.79	+0.54
Rupestris St. George	33.2 ±2.46	−4.58	5.1 ±0.30	−7.50
Solonis ×Othello, No. 1613	51.6 ±3.17	—	7.8 ±0.19	—
Monticola ×Riparia, No. 18815	40.6 ±2.67	−2.66	6.5 ±0.15	−5.42
Riparia ×Rupestris, No. 3309	48.2 ±4.28	−1.80	8.3 ±0.50	+0.89
Solonis ×Othello, No. 1613	58.2 ±3.54	—	7.8 ±0.24	—
Dog Ridge	40.6 ±4.85	−2.94	9.6 ±0.63	+2.61
	Black Monukka			
Mourvedre ×Rupestris, No. 1202	47.0 ±2.38	+1.22	10.7 ±0.84	−0.97
Solonis ×Othello, No. 1613	43.2 ±1.99	—	11.6 ±0.39	—
Berlandieri ×Riparia, No. 420-A	38.5 ±3.53	−1.85	10.1 ±0.55	−2.24
Chasselas ×Berlandieri, No. 41-B	55.2 ±3.61	+2.43	8.2 ±0.67	−3.37
Solonis ×Othello, No. 1613	44.5 ±2.55	—	11.3 ±0.63	—
Constantia	29.3 ±1.06	−5.52	11.8 ±0.74	+0.52
Rupestris St. George	34.6 ±3.03	−3.99	8.5 ±1.11	−3.06
Solonis ×Othello, No. 1613	47.8 ±1.36	—	12.2 ±0.52	—
Monticola ×Riparia, No. 18815	41.7 ±2.57	−2.10	9.8 ±0.45	−3.53
Riparia ×Rupestris, No. 3309	42.2 ±2.47	−0.97	9.1 ±1.06	−2.46
Solonis ×Othello, No. 1613	45.5 ±2.32	—	11.9 ±0.47	—
Dog Ridge	35.3 ±2.27	−3.15	8.8 ±0.94	−2.96
	Corinthe Noir			
Mourvedre ×Rupestris, No. 1202	—	—	—	—
Solonis ×Othello, No. 1613	37.1 ±1.66	—	8.7 ±0.65	—
Berlandieri ×Riparia, No. 420-A	28.2 ±2.14	−3.34	4.3 ±0.59	−5.00
Chasselas ×Berlandieri, No. 41-B	33.2 ±8.22	−1.19	5.1 ±0.72	−2.24
Solonis ×Othello, No. 1613	37.9 ±2.29	—	7.0 ±0.46	—
Constantia	23.7 ±2.18	−4.50	4.4 ±0.46	−4.00
Rupestris St. George	21.2 ±1.26	−3.34	4.3 ±0.47	−2.24
Solonis ×Othello, No. 1613	30.1 ±2.35	—	6.4 ±0.82	—
Monticola ×Riparia, No. 18815	25.0 ±1.60	−1.80	4.9 ±0.46	−1.60
Riparia ×Rupestris, No. 3309	31.3 ±3.20	−0.10	5.3 ±0.73	−1.47
Solonis ×Othello, No. 1613	31.7 ±2.27	—	6.7 ±0.61	—
Dog Ridge	29.6 ±2.78	−0.59	6.3 ±0.71	−0.46

*Difference from the standard of comparison, Solonis ×Othello, No. 1613, in terms of probable error. Differences are not to be considered significant unless they are at least three times the probable error, which means that the odds against such differences occurring under uniform conditions are 22 to 1.

parative readings are not at the significant level, the trend indicates the value of the standard rootstock Solonis x Othello, No. 1613 for this variety.

Malaga:—The fruit weights on the rootstocks Berlandieri x Riparia No. 420–A and Monticola x Riparia, No. 18815 exceeded the standard but wood weights were considerably lower. Constantia gave plus ratings in both fruit and wood weights but not at significant levels. Chasselas x Berlandieri, No. 41–B was even in fruit weight but decidedly low in wood weight. Most of the stocks for the period of this test were satisfactory for Malaga and none decidedly superior to the standard, Solonis x Othello, No. 1613.

Flame Tokay:—Mourvedre x Rupestris, No. 1202 gave plus ratings for both fruit and wood in comparison with the standard. Constantia was even in fruit and higher in wood weight, which would indicate a slightly better rating than Solonis x Othelle, No. 1613. Rupestris St. George was quite inferior in both fruit and wood. Riparia x Rupestris, No. 3309 was lower than the standard in both fruit and wood, while Berlandieri x Riparia, No. 420–A and Chasselas x Berlandieri, No. 41–B were lower in wood. Dog Ridge was decidedly lower in fruit than the standard and practically even in wood weight. Mourvedre x Rupestris, No. 1202, Constantia, and the standard, Solonis x Othello, No. 1613 were the better stocks for Flame Tokay in this test. Since Mourvedre x Rupestris, No. 1202 and Constantia are more susceptible to rootknot nematode injury, their use for general planting would be limited.

Alphonse Lavallee, (Ribier):—Minus ratings exceeded the plus ratings in the comparisons with the standard. Chasselas x Berlandieri, No. 41–B gave a plus reading for fruit but was on the minus side for wood. Constantia and Dog Ridge were the low ranking stocks for this variety. Rupestris St. George was low in fruit weight. Mourvedre x Rupestris, No. 1202, Berlandieri x Riparia, No. 420–A, Monticola x Riparia, No. 18815, and Riparia x Rupestris, No. 3309 appeared to be of value for this variety but not decidedly better than Solonis x Othello, No. 1613.

Emperor:—Berlandieri x Riparia, No. 420–A, Chasselas x Berlandieri, No. 41–B, and Rupestris St. George were low in weight of wood. Mourvedre x Rupestris, No. 1202, Constantia, Monticola x Riparia, No. 18815, and Riparia x Rupestris, No. 3309 were on the plus side in weight of fruit. Considering both fruit and wood, Mourvedre x Rupestris, No. 1202, and Constantia appeared equal to but not decidedly better than the standard, Solonis x Othello, No. 1613.

Sultanina:—The preponderance of minus signs in D/PE columns for both wood and fruit weights are apparent. Berlandieri x Riparia, No. 420–A was the only stock which compared favorably with the standard. Mourvedre x Rupestris, No. 1202, Chasselas x Berlandieri, No. 41–B, and Constantia gave somewhat poorer records than the standard. Dog Ridge, Monticola x Riparia, No. 18815, Riparia x Rupestris, 3309, and Rupestris St. George were the lower rating stocks for this variety. The general trend indicates the standard,

Solonis x Othello, No. 1613, was a very satisfactory stock for this variety. In fact the average of all checks of Sultanina grafted on Solonis x Othello, No. 1613 was 11.3 tons of fruit per acre per year for the 9-year period.

Ohanez:—Minus signs predominate over plus signs, especially in the case of wood weights. Chasselas x Berlandieri, No. 41–B, Berlandieri x Riparia, No. 420–A, Dog Ridge, Rupestris St. George, and Riparia x Rupestris, No. 3309 were decidedly low in wood weights, although they were nearly equal or slightly better in fruit weights. Monticola x Riparia, No. 18815 was low in both fruit and wood weights. Insufficient vines on Mourvedre x Rupestris, No. 1202 removed this stock from the comparative test. Constantia was the nearest in performance to the standard stock, Solonis x Othello No. 1613.

Castiza:—Mourvedre x Rupestris, No. 1202, Rupestris St. George, and Monticola x Riparia, No. 18815 were the low ranking stocks in both fruit and wood. Berlandieri x Riparia, No. 420–A, and Chasselas x Berlandieri, No. 41–B gave plus signs for fruit but these were offset by decidedly lower wood weight records. Constantia, Dog Ridge, and Riparia x Rupestris, No. 3309 were slightly higher in wood weights but on the low side in fruit production. The standard was as good as or better than the other stocks for this variety.

Black Monukka:—In the comparisons with the standard the minus signs exceeded the plus signs for both fruit and wood production. In a portion of this test, rootknot nematode infestations affected the susceptible stocks in these comparisons. Mourvedre x Rupestris, No. 1202 was out of the infested area and did not appear to be affected and compared favorable with the standard in both fruit and wood. Berlandieri x Riparia, No. 420–A, Constantia, Monticola x Riparia, No. 18815, Rupestris St. George, and Dog Ridge were the lower ranking stocks with this variety. Chasselas x Berlandieri, No. 41–B gave a plus sign for fruit weight but a larger minus reading for wood growth. Riparia x Rupestris, No. 3309 was nearly equal to the standard in fruit weight but was low in wood weight. Solonis x Othello, No. 1613 gave uniformly good fruit and wood weight records for this variety.

Corinthe Noir:—All stocks gave minus values for both fruit and wood when compared with the standard. This was largely due to the fact that one replication of the grafted vines occurred in soil where the rootknot nematode was present. It may be noted that Dog Ridge, which has some resistance to nematode (2), is the only stock that compares favorably with the standard, Solonis x Othello, No. 1613 for the Corinthe Noir variety. The records for this variety tend to stress the need of a rootstock resistant to nematode injury as well as resistant to phylloxera.

SUMMARY

This report presents the results of a comparative test of nine selected grape rootstocks grafted with 10 vinifera varieties conducted at the United States Horticultural Field Station, Fresno, California, over

the period 1932 to 1945 inclusive. Fruit and wood weight records were obtained for the years since full production, 1937 to 1945 inclusive.

Rooted stock vines produced nearly a perfect stand in the vineyard irrespective of the variety of rootstock. In general the vigorous rootstocks produced the most wood weight (pruning brush) the first season of growth. The varieties grew well on all stocks with the exception of Ohanez on Mourvedre x Rupestris, No. 1202, which appeared to be due to a mechanical defect in grafting rather than a lack of affinity between stock and scion. The more vigorous stocks increased faster than the weaker stocks in circumference, and stocks under vigorous vinifera varieties had larger increases in circumference than the same stocks under weaker varieties.

Over the period of fruit and wood weight records, 1937 to 1945 inclusive, no wide differences of the vinifera varieties on the different rootstocks were apparent. Towards the end of the test, the varieties on the weaker stocks were producing somewhat less wood growth, but holding up fairly well in fruit production. This may indicate that a comparative stock test, especially with well chosen stock varieties should run longer than the period of this test. The standard stock, Solonis x Othello, No. 1613, was as good as or better than the other stocks for the varieties tested.

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Maturity Tests for Table Grapes — The Relation of Heat Summation to Time of Maturing and Palatability

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A TABLE grape is mature when it can be eaten with satisfaction. But how to determine maturity accurately without the eating has been, and still is, a problem. The earlier workers (1) concerned themselves solely with chemical analyses. Later (2) an attempt was made to correlate the level of the principal components of the fruit with eating quality. The results of this investigation led to the establishment of degree Balling as a basis of standardization in the shipment of table grapes in and from California. Degree Balling alone, however, does not always give an accurate indication of palatability. In most years and regions the measurement is satisfactory, but in some the fruit may meet the required degree Balling and still be unpalatably sour, while in others the fruit may be palatable before it reaches the required degree Balling. Further organoleptic and chemical analyses (3) have served as a basis for combining the acidity of the grape with its degree Balling into a Balling-acid ratio as a means of measuring maturity. Although not so readily applied, this combination corrects some of the defect of degree Balling alone. Of even greater importance than devising a better measure of the maturity of table grapes this investigation focused attention on the summation of heat and its influence on the time of ripening and on the level of the acidity at a given degree Balling. It is this influence that will be discussed.

A study of the relations of the heat summation was initiated in the early 1930's following four seasons of work with organoleptic and chemical analyses. Two significant periods of heat summation have been disclosed: (a) from blooming to the legal minimum degree Balling (or other defined degree of maturity) and (b) the ripening period of the variety being studied. By effective heat summation, as used here, is meant the summation of the mean daily temperature above 50 degrees F. The summation is expressed as degree-days.[1] The ripening period varies with the variety. An early-maturing sort will have a relatively short ripening period as compared to a late-maturing one. Likewise, in a hot region all processes concerned with fruit development go forward more rapidly, and the ripening period is shorter. For instance, the fruit of the variety Thompson Seedless develops from blooming to a maturity of 18 degrees Balling in the Coachella Valley — a hot desert region — in approximately 68 days, and the ripening period covers about 21 days; while at Davis, a moderately warm region, 90 or more days are required from blooming to 18 degrees Balling, and the ripening period covers 30 days.

Fruit was collected of each of the table grape varieties at approximately the beginning of the commercial harvest from each of the prin-

[1]A degree-day is one degree F above 50 degrees F for 24 hours. For example, if the mean temperature for a day was 70 degrees F, the summation would be 20 degree-days, and if the mean for June was 65 degrees F, the summation would be 450 degree-days.

cipal producing regions. During the first four years organoleptic analyses by a jury of at least six individuals preceded the chemical analyses of each sample of fruit. The organoleptic analyses of these samples not only indicated their palatability, but along with the degree Balling and acidity determinations they made it possible to fix a definite minimum degree Balling plus a Balling-acid ratio at which the fruit of each variety would be sufficiently mature to be eaten with satisfaction. Some 4,000 samples were run in this fashion, while degree Balling and per cent acid determinations were made on several times this number of additional samples.

The blooming dates at Davis were determined by careful observations which were correlated with the temperature records. At the stations away from Davis the blooming dates were fixed by general observations and by use of the daily mean temperatures.

Thompson Seedless

This, the leading table grape of California, is also grown under the most widely divergent climatic conditions. Samples were collected from Coachella Valley, the hottest region in which grapes are grown in California, and from Kern County, Fresno County, and Davis, regions of less heat, the temperature decreasing in the order named.

The summation of heat from full bloom to a maturity of 18 degrees Balling for the Thompson Seedless during 12 years in the Coachella Valley varied from 1930 to 2081 degree-days; for 15 years, in Kern County, it varied from 1965 to 2065 degree-days; for 14 years, in Fresno County, it varied from 1958 to 2054 degree-days; and for 8 years at Davis it varied from 1974 to 2025 degree-days. When one considers that the daily heat accumulation in mid- and late-summer in these regions lies between 20 and 40 degree-days, it is apparent that the rounded average figure of 2000 degree-days fixes the date within ± 2 days, which is about as close as it can be determined with limited random degree Balling determinations.

Although the figure of 2000 degree-days following full bloom definitely indicates the degree Balling of the fruit, it does not insure satisfactory eating quality. This quality of the fruit is influenced more by the summation of heat during the ripening period. At a given degree Balling, say 18, the acidity of grapes varies inversely with the temperature during the ripening period. If the period is hot, the acid is relatively low, and the fruit tastes agreeably sweet; if cool, the acid is high and the fruit sour. Approximately one-third of the fruit in the ripening range (17 to 19 degrees Balling) was of good eating quality when the summation of heat for the ripening period was well above normal. With a drop in the heat summation to normal, the percentage of fruit that was of good eating quality dropped sharply. With a summation considerably below normal for the ripening period, but very little of the fruit was palatable.

To those not familiar with grape production, it may appear that grapes are not mature when only one-third of the fruit is good to eat. This is not the case at all, since the grapes in a single vineyard do not all ripen at exactly the same time, and early-maturing varieties are

regularly picked over several times in order to get the ripe fruit as early as possible. Actually, many growers start harvesting with even a smaller percentage of mature fruit.

MALAGA

In the case of this variety the heat summation required to bring the fruit from blooming to 18 degrees Balling for the Coachella Valley and Kern and Fresno counties was 2150 ($\pm$ two days) degree-days.[2] The fruit in the ripening range of 17 to 19 degrees Balling was good to eat or sour according to the summation of heat during the ripening period, as with Thompson Seedless.

RED MALAGA AND RIBIER

When ungirdled, these two varieties require the same summation of heat as the Malaga to bring them to the minimum degree Balling requirement. On the other hand, when they are girdled near the beginning of ripening, to hasten maturing, they come in with the Thompson Seedless at 2000 degree-days. That is, 2000 degree-days will bring these varieties from blooming to the required 16 degrees Balling when they are properly girdled, while if not girdled 2150 degree-days are needed. The influence of heat summation during ripening is the same as indicated for the other varieties.

EMPEROR

The Emperor is the latest maturing variety that is grown extensively in California. Figures for 10 years on the heat requirement of this variety indicate that 3300 degree-days will bring it from blooming to 16 degrees Balling. Although fairly accurate, this figure is of less significance with a late-maturing sort, since there is no incentive to begin harvesting at the earliest possible moment. Similarly, the heat summation during the ripening period loses effectiveness because this sum is increased over the normal by the usual delay in the beginning of the harvest.

TOKAY

As was previously reported (4) the Tokay is brought from blooming to a satisfactory minimum degree Balling by a summation of 2250 degree-days. But the fruit was palatable or not according to the summation of heat for the ripening period (4 weeks prior to harvest). With a summation from blooming of 2250 degree-days and a summation of 700 or more degree-days for the ripening period, the fruit was very good; with 670 degree-days during ripening, the fruit was good; and with 640 or less degree-days for the ripening period, it was sour.

[2]Some growers and shippers may question the 2150 degree-days from blooming to 18 degrees Balling, since the Malaga is usually not harvested so soon after the Thompson Seedless. The delay in harvesting, however, is not due to lack of maturity of the Malaga fruit, but owing to the fact that in the early sections, where earliness counts, most of the growers also grow the more popular Thompson Seedless, and they are busy getting it harvested.

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Germination of Strawberry Seed as Affected by Scarification Treatment with Sulfuric Acid

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THE time of emergence of strawberry seedlings may vary in the same lots from 10 to 140 days from date of seeding. Powers (5) has shown a wide spread in time of emergence in germination chambers where conditions were uniform over a long period of time. In genetic studies and in some plant breeding work this may be a disturbing factor when seedlings of uniform size are necessary and where high germination is essential. The delayed germination has caused trouble in the breeding work for red stele resistance, as seedlings planted late in the season do not become so severely infected with the red stele organism as those planted earlier (2).

Since sulfuric acid has been used as a scarifying agent on some seeds (1), it was tried on strawberry seeds and the results are reported here.

METHODS AND MATERIALS

Seeds were used from two different crosses (Fairpeake x Suwannee and Eleanor Roosevelt x Massey) that were made in March 1946. The fruits were harvested in April and the seeds separated from the pulp with a Waring Blendor as recommended by Morrow (4). They were dried and then placed in a desiccator containing $CaCl_2$ and stored in a refrigerator at 40 degrees F until time of treatment on January 8, 1947. The scarification treatment consisted in soaking the seeds in 10 cc concentrated sulfuric acid per 1,000 seeds for 15 minutes with constant agitation, washing the seeds for 30 minutes in running tap water, drying them on blotters for 3 hours, and then seeding. Preliminary data indicated that there was no difference between 10- and 15-minute treatments, but more than 20 minutes was apt to be very injurious. One thousand seeds per plot were planted on shredded sphagnum in flats 12 by 24 by 3 inches. There were three plots of treated seeds and three check plots for each cross, making a total of 12 plots and 12,000 seeds. The flats were placed on a greenhouse bench to germinate where the temperature was 75 to 80 degrees F in the day and 65 to 70 degrees at night. Henry (3) has shown that strawberry seeds germinate well at temperatures of 75 to 85 degrees F.

RESULTS AND DISCUSSION

The results on time of emergence of seedlings are shown in Table I. The first emergence was recorded 8 days from date of seeding in plots where the seeds were scarified with sulfuric acid. Four days later the first seedlings appeared in the check lots. Twelve days from date of seeding the treated plots had approximately 50 per cent germination, whereas it was about 20 days from seeding before the check plots had 50 per cent germination. Most of the germination had occurred in all plots within 40 days, although some seedlings emerged in the interval

TABLE I—EFFECT OF TREATMENT OF NINE-MONTH OLD STRAWBERRY SEEDS WITH CONCENTRATED SULFURIC ACID ON TIME OF EMERGENCE OF SEEDLINGS IN TWO POPULATIONS (SEEDED JANUARY 8, 1947, 1,000 SEEDS PER PLOT, THREE PLOTS PER TREATMENT)

Population	Treatment	Per Cent of Seedlings Emerged on Indicated Number of Days from Date of Seeding										
		8	9	12	14	16	19	21	26	41	55	X^2
Eleanor Roosevelt × Massey	Acid treated	12.5	25.6	47.9	52.9	56.4	60.2	62.6	64.8	68.3	71.0	*
	Check	0	0	3.3	5.1	9.4	20.0	29.7	55.6	69.0	74.5	
Fairpeake × Suwannee	Acid treated	18.6	31.9	50.3	55.3	62.9	65.5	69.2	70.4	72.7	75.9	*
	Check	0	0.2	4.9	9.9	21.1	36.3	48.0	72.5	82.4	88.9	

*Highly significant difference between treated and check treatments.

of 40 to 55 days. Lack of greenhouse space necessitated discontinuance of the time of emergence records 55 days from date of seeding, but germination for the most part appeared to be completed. Although the acid scarification hastened the germination of the seeds, it did not overcome the tendency for them to germinate over a prolonged period. The scarification treatment was sufficient to char the seed coat, which probably made it fully permeable to water or gases, and consequently it is concluded that the delay in emergence of seedlings is not a seed coat effect.

Germination at the end of 55 days when the experiment was terminated shows that scarifying the seeds with concentrated sulfuric acid for 15 minutes lowered the percentage of germination significantly in both crosses, although not seriously so in the Eleanor Roosevelt x Massey seeds.

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Breeding Autumn-Fruiting Raspberries: Third Report[1]

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THIS third report on the breeding of autumn-fruiting raspberries at the New York State Agricultural Experiment Station deals with crosses made in 1945 which bore their first fall crop in 1947. The first report in 1939 (1) dealt with crosses between Indian Summer and its sibs, Indian Summer and closely related clones derived from Lloyd George, and Indian Summer and unrelated varieties. The value of Lloyd George and its offspring as parents in producing autumn-fruiting raspberries was indicated. The second report in 1944 (2) dealt briefly with crosses between clones derived from the matings discussed in the first report. Those crosses were mostly between closely relate seedlings, being sib crosses, half sib crosses, back crosses and selfs. A great reduction in vigor of the resulting seedlings occurred and very few seedlings of any merit were produced. Even when both parents were autumn-fruiting the percentage of autumn-fruiting seedlings was small and very few ripened the fall crop early enough to be of value. Accordingly, a different approach was adopted.

Materials and Methods

It appeared necessary to broaden the base in the raspberry breeding project and build up a stock of clones of a more diverse genetic nature to take advantage of the phenomenon of hybrid vigor. For this purpose the principal parents included several clones derived from Lloyd George, and early autumn-fruiting selections of *Rubus strigosus* from Oswego county, New York. Several varieties and selections not related to Lloyd George were also used. In view of the excellent results obtained from using Lloyd George in previous breeding operations, St. Walfried, another apparently pure *Rubus idaeus* variety from Europe, was used because of its large size and the vigor that might result from combinations with another species. It was hoped that seedlings paralleling those obtained from earlier breeding work with Lloyd George might be obtained, but having a different genetic constitution.

The seedlings were started in the greenhouse in March, 1946 and moved from pots in late May to the fruiting plantation where they were interplanted between rows of seedling tree fruits. Good growth was made in 1946 and fairly good growth in 1947. August and September 1947 were unusually dry so that berry size was undoubtedly reduced somewhat. Wind whipping also bruised the ripening berries in late September. Cool weather in August delayed the fall crop so that it was about 2 weeks later than normal, but hot weather later permitted much of the fall crop to ripen on the earlier seedlings.

The seedlings were inspected at intervals of about 10 days and tagged when ripe. At the end of the season, or about October 10, all seedlings not previously marked were classified as to the state of de-

[1]Journal Paper 742, New York State Agricultural Experiment Station, Geneva, N. Y. December 1947.

velopment of the fall crop. In one class were those that were just beginning to bloom, in another those that were farther advanced and had unripe berries only. A third category included a few plants in which only one cane had ripe berries, but with the other canes not flowering.

Results

The percentage of seedlings ripened each week in each population, as well as those with unripe berries and flowers only are tabulated in Table I. The percentage of each population considered worthy of retaining for further testing is indicated. Only populations producing seedlings with ripe berries are included in this table.

The breeder of autumn-fruiting raspberries is concerned principally with those that begin ripening the fall crop not later than September 1 at Geneva, New York, but in view of the lateness of the 1947 season, September 15 is considered in this paper to be the latest acceptable date for fall bearing raspberries to begin ripening.

TABLE I—Season of Ripening of Fall Crop from Raspberry Crosses (1947)

	Seedlings Raised	Per Cent Selected	Aug 26–Sep 1	Sep 2–Sep 8	Sep 9–Sep 15	Sep 16–Sep 22	Sep 23–Sep 29	Sep 30–Oct 10	One Cane Only Autumn Fruiting	Unripe Berries Only	Flowers Only	Total Autumn-Fruiting
September ×20903	250	—	3.0	6.8	13.6	7.0	3.6	15.1	1.2	25.2	12.8	88.8
September ×20990	195	1.5	—	16.4	14.9	6.7	9.2	16.9	—	14.9	8.7	87.7
September ×15979	609	—	—	0.1	0.8	0.5	1.5	3.3	3.0	13.4	16.0	38.6
16610 ×September	553	0.5	—	0.7	1.8	0.5	3.6	6.8	1.1	12.1	17.1	43.9
14477 ×September	922	—	—	0.2	0.3	0.4	1.7	2.6	0.7	11.0	14.6	32.8
14477 ×20990	128	0.8	—	—	2.3	1.5	14.8	7.0	1.5	25.8	10.1	63.3
Milton ×20990	240	0.4	—	—	1.2	—	3.3	4.2	2.1	26.6	19.6	57.0
St. Walfried × 20990	37	—	—	5.4	2.7	2.7	5.4	10.8	2.7	21.6	16.2	67.6
St. Walfried × 20903	361	—	—	1.1	3.0	0.8	6.1	6.1	0.5	23.2	21.0	62.0
Milton ×20903	82	—	—	—	1.2	1.2	1.2	2.4	1.2	9.7	12.2	31.7
Ripening dates of autumn-fruiting parents:												
September	—	—	—	—	X	—	—	—	—	—	—	—
20903	—	—	—	—	X	—	—	—	—	—	—	—
20990	—	—	X	—	—	—	—	—	—	—	—	—

The 10 populations in Table I represent 3377 seedlings of which one or both parents are autumn-fruiting. Of these seedlings only 170 or 5 per cent, began ripening before September 15. In the crosses between September and 20903 and 20990 both parents are autumn-fruiting and begin before September 15, but only 120 or 27 per cent of 445 seedlings ripened before September 15. In the eight other crosses with one parent autumn-fruiting, only 50 or 1.6 per cent of 2932 seedlings ripened before September 15.

In the five populations in Table II in which one parent in each combination is autumn-fruiting only 207 or 14.9 per cent of 1322 seedlings were autumn-fruiting and none of these produced ripe berries.

Of the 4701 seedlings from 15 different crosses listed in Tables I and II from which autumn-fruiting seedlings might be expected, only

TABLE II—AUTUMN FRUITING HABIT IN CROSSES NOT PRODUCING RIPE BERRIES

Crosses	Number Set in Field	Per Cent Autumn-Fruiting
17861 ×September	667	14.2
14619 ×September	100	0.0
14619 ×Lloyd George	79	0.0
Latham ×20990	41	0.0
Latham ×20903	435	25.7

Origin of parents:
Milton = Lloyd George × Newburgh (Newman × Herbert)
14477 = Newburgh (Newman × Herbert) × Lloyd George
14619 = Newburgh (Newman × Herbert) × Viking
15979 = June × Newburgh (Newman × Herbert)
16610 = Indian Summer (1950 × Lloyd George) × Cayuga (June × Cuthbert)
17861 = Newburgh (Newman × Herbert) × Indian Summer (1950 × Lloyd George)
20903 = *Rubus strigosus*—early autumn-fruiting.
20990 = *Rubus strigosus*—early autumn-fruiting.
St. Walfried = *Rubus idaeus* variety of recent Dutch origin.
September = Marcy (Lloyd George × Newman) × Ranere
An autumn-fruiting variety introduced by the New York (Geneva) Station in the fall of 1947. The fall crop starts to ripen from 2 to 4 weeks earlier than the fall crop of Indian Summer.

eight selections were made and of these only three began ripening before September 15 and only two could be considered promising in themselves.

Discussion

The production of early ripening autumn-fruiting raspberries suitable for commercial purposes as well as for home use is not easy. In the three attempts, of which this is the third, progress has been much slower than if the same efforts were expended on breeding summer-fruiting raspberries or strawberries. The small numbers of early autumn-fruiting seedlings produced make necessary the growing of very large populations of a number of different combinations. It will be difficult to produce large numbers of early ripening seedlings possessing the essential characteristics of large size, bright red color, firmness, freedom from crumbling and high dessert quality, combined with such plant characters as vigor, productiveness, hardiness and virus resistance. These characteristics are available chiefly in varieties from which good results in breeding early autumn-fruiting raspberries have not yet been obtained.

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Effect of Soil Management on Yields, Growth, and Moisture and Ascorbic Acid Content of the Fruit of Cultivated Blueberries

By W. H. Griggs and H. A. Rollins, *University of Connecticut, Storrs, Conn.*

Previous work (5) on the most desirable soil management for three horticultural varieties (Jersey, Rubel and Wareham) of highbush blueberries (*Vaccinium corymbosum*, L) has shown that those mulched with sawdust gave higher yields and made greater shoot growth than similar plants under either clean cultivation or hay mulch. As the significant differences in both yield and shoot growth were observed in the third cropping year only (1946), the yield and shoot growth have now been recorded for the fourth year (1947) to determine whether such favorable response would persist.

In addition, the fruit from plants included in the experiment was analyzed for ascorbic acid content. It has been found with vegetables that climatic factors previous to harvest, particularly variations in light intensity, exert greater influence on the content of ascorbic acid than such variables as variety, soil type, length of day or fertilizer application (6, 8, 9, 10). Lineberry and Burkhart (13) found differences in the ascorbic acid content of strawberries due to variety as well as to sunshine and location in the field. Hansen and Waldo (7), also working with strawberries, related the variations in vitamin C potency for individual varieties to differences in the climatic conditions prevailing during growth and ripening. Salerno (16) noted that the ascorbic acid content of two species of fresh barberries (*Berberis Thunbergii*, DC. and *Berberis vulgaris*, L.) dropped appreciably with the onset of very cold weather.

Although numerous investigators have shown that the ascorbic acid content of certain fruits and vegetables may vary under different conditions, the effect of soil management on the ascorbic acid and moisture content of blueberries has not been reported. The ascorbic acid content of several varieties of highbush blueberries, ranging from 7.5 to 24.7 milligrams per 100 grams of fresh fruit, has been reported by workers from different stations (1, 2, 4, 11, 13, 14). Lineberry (13), Brewer and Levcowich (1) and Fellers and Merriam (3) found very little difference in ascorbic acid content between different varieties in North Carolina, New Hampshire and Massachusetts respectively, while Kirk and Tressler (11) found a range of 12 to 20 milligrams in New York.

Materials and Methods

The plan in this experiment as reported (5) consisted of 30 plants of each of three varieties of highbush blueberries (Jersey, Rubel and Wareham) set 5 feet by 10 feet apart in 18 plots. A single plot consisted of one row of five plants of one variety. The plants were set in the spring of 1941 and cultivated during their first growing season. Mulches were applied in the fall of 1941 and the plants were grown

under either clean cultivation, sawdust mulch, or hay mulch, two plots of each variety receiving each treatment. Beginning in 1942 each plant received 1 ounce of 5–10–5 commercial fertilizer, and the amount applied has been increased by 1 ounce each year thereafter.

The ascorbic acid and moisture content of the fruit were determined on pooled samples from each plot on three different picking dates: July 31, August 4 and August 7, near the middle of the harvest season. Ascorbic acid was determined from duplicate samples by the Loeffler and Ponting method (15), and moisture content from duplicate samples of 10 punctured berries (15 to 20 grams) at 70 degrees C for 24 hours.[1] These tests were made upon mature, sound fruit picked in the forenoon, and all analyses were completed within 24 hours from the time of picking.

Yields and linear shoot growth for 1947 were recorded for each plant. The data were anlyzed statistically under the direction of C. I. Bliss, biometrical consultant, Storrs Agricultural Experiment Station.

Results and Discussion

The 1947 mean yields per plant, the linear shoot growth per plant for 1946 and 1947, and the moisture and ascorbic acid contents of the fruit at different picking dates are presented in Table I for each type

TABLE I—Yields, Growth, and Moisture and Ascorbic Acid Content of Fruit of Cultivated Blueberries as Affected by Soil Management*

	Mean Yield Per Plant (Pints)	Mean Linear Shoot Growth Per Plant (Centimeters)		Moisture Content (Per Cent)				Ascorbic Acid (Milligrams Per 100 Grams Fresh Weight)			
	1947	1946	1947	1947				1947			
				Jul 31	Aug 4	Aug 7	Sep 18	Jul 31	Aug 4	Aug 7	Sep 18
Treatment											
Sawdust mulch...	34.43	16.75	17.14	85.22	84.12	83.49	82.29	10.76	7.04	11.96	4.62
Hay mulch	19.30	12.99	11.47	85.22	83.79	83.30	80.78	10.80	6.73	12.07	3.46
Clean cultivation...	23.96	13.90	13.07	85.68	84.59	83.48	83.70	10.21	6.44	11.84	5.54
Variety											
Rubel.....	34.91	15.42	12.16	85.09	84.07	82.88	80.71	10.07	6.66	11.15	3.89
Jersey.....	23.60	15.42	14.83	86.04	84.53	83.54	83.03	10.35	7.44	10.06	4.54
Wareham..	19.18	12.80	14.69	84.99	83.91	83.85	83.01	11.35	6.10	14.66	5.27
General mean	25.90	14.55	13.89	85.37	84.17	83.42	82.25	10.59	6.74	11.96	4.55
Differences required for significance											
5.0 per cent level	7.58	2.20	2.55	—	—	—	—	—	1.11	0.93	—
1.0 per cent level	10.70	3.11	3.60	—	—	—	—	—	1.56	1.30	—

*Each value represents the plant average for six plots.

of soil management and variety. In general, the 1947 growth and yield data corroborate the results obtained in 1946 (5). Plants of all three varieties under sawdust mulch yielded on the average significantly

[1]The authors wish to express their great appreciation to Miss Catherine Cowell of the School of Home Economics, who made the moisture and ascorbic acid determinations.

more (34.43 pints) than those under clean cultivation (23.96 pints) or hay mulch (19.30 pints). In comparing variety yields averaged over the three types of soil management, Rubel yielded significantly more per plant (34.91 pints) than either Jersey (23.60 pints) or Wareham (19.18 pints). As in 1946 (5), the yield of Rubel again showed a greater increase with sawdust mulch than did that of the other two varieties, giving the only significant interaction between soil management and variety.

The average linear shoot growth of the sawdust-mulched plants (17.14 centimeters) exceeded significantly that of plants under either clean cultivation (13.07 centimeters) or hay mulch (11.47 centimeters). Although alike in their average increase in 1946, Jersey made significantly more growth in 1947 than Rubel. The difference may be partially explained by the extremely heavy fruit set and high yields made by Rubel in 1947. After correcting differences in variety and treatment, the mean yield in pints in 1947 was related to the average linear growth in centimeters during 1946. The yield increased on the average by 1.89 ± 0.91 pints for each centimeter of growth.

Neither variety nor type of soil management had any significant effect upon the moisture content of the fruit. There were also no significant differences in ascorbic acid content of the fruit related to the three forms of soil management. Although the fruit picked July 31 showed no significant varietal differences in ascorbic acid content, small variations occurred at the later pickings. The similarity found here in the ascorbic acid content of fruit produced by three different varieties of highbush blueberry plants growing under three types of soil management supports the conclusions based upon other crops (6, 7, 8, 9, 10, 12) that factors such as variety, soil type, fertilizer, and so on are less important in affecting the ascorbic acid content of fruits than certain climatic factors.

In an attempt to find an explanation for the lower ascorbic acid content of the fruit harvested on August 4,[2] a study was made of the weather records[3] preceding each sampling date. Clear weather prevailed before and during each picking. The mean daily temperatures for the day prior to each sampling date (July 31, August 4 and August 7) were 76 degrees F, 68 degrees F, and 76 degrees F, respectively. The minimum temperatures on the three days preceding sampling averaged 64 degrees F for the July 31 picking, 54 degrees F for August 4, and 62 degrees F for August 7. Thus, it appears that the lower temperatures preceding the August 4 sampling may have been responsible for the lower content of ascorbic acid.

As a partial check on this hypothesis, the few remaining berries were picked from the plants on September 18. The mean temperature for the preceding day was 62 degrees F, and the minimum temperatures for the three preceding days averaged 55 degrees F. Clear weath-

[2]Ascorbic acid determinations of canned tomatoes made by the same analyst during this period, by both the photoelectric and visual titration methods, showed that the low values for blueberries found on this data were not due to errors in technique.

[3]U. S. Department of Commerce, Weather Bureau, Monthly Climatological Summary (WB Form 1030) Hartford, Connecticut.

er also prevailed prior to, and on the day of this last sampling. Thus, the weather conditions before the September 18 sampling approximated those prior to that on August 4.

The ascorbic acid content of the fruit harvested on September 18 averaged slightly less than that picked on August 4. The differences in ascorbic acid content of fruit from the three types of soil management and from the three varieties were considered insignificant since at this time the berries were relatively small and ranged from ripe to overripe. The fact that the ascorbic acid content of the fruit was again low on September 18 following three cold days suggests that low temperatures before picking may reduce the ascorbic acid content of blueberries.

Summary

Results from the fourth cropping year on three horticultural varieties of highbush blueberries confirmed an earlier report that mulching with sawdust gave greater growth and better yields than either clean cultivation or hay mulch. The Rubel variety again yielded more, whereas Jersey and Wareham made greater shoot growth.

After eliminating statistically the effect of soil management and variety, shoot growth made in 1946 increased the yield in 1947 by an average of 1.89 ± 0.91 pints per centimeter.

Neither the moisture nor the ascorbic acid content of the berries varied significantly as a result of the different types of soil management.

A lower ascorbic acid content in berries picked on two out of four sampling dates seemed to be associated with relatively low temperatures on the three days prior to picking.

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Fertilizer Response of Blueberry Hardwood Cuttings[1]

By C. D. Schwartze and Arthur S. Myhre, *Western Washington Experiment Station, Puyallup, Wash.*

In the propagation of the highbush blueberry from hardwood cuttings the medium most commonly employed is sphagnum peat or a mixture of peat and sand, neither of which is well supplied with plant nutrients. Rooting takes place in June and July, allowing the remainder of the summer and fall for subsequent plant growth. Ordinarily, shoot growth has been limited to not more than a few inches, the color of leaves has been pale green to yellow and red and growth has terminated in late summer or early fall. These symptoms of nutrient deficiency have suggested that the application of plant nutrients to the propagating medium might be beneficial. No experimental evidence in support of this practice has been published so far as the writers are aware, although Doehlert (1) has suggested that a nutrient solution containing nitrogen, phosphorus and potash might be applied to the propagating beds at weekly intervals from the time the cuttings are rooted until mid-August. Gardner (2) has mentioned an instance in which fertilization of blueberry cuttings was detrimental. Similar experience has been reported verbally by commercial propagators. The fertilizers used and rates of application have not been stated. An experiment was conducted at the Western Washington Experiment Station, Puyallup, Washington in 1947 to determine the desirability of fertilizing blueberry propagation beds and the relative effectiveness of certain fertilizing materials.

Materials and Methods

Cuttings were rooted in sash-covered frames under a lathhouse. The medium was a mixture of three parts high grade horticultural peat and one part sand. The frames were divided into 20 3 by 3 foot sections, in half of which the medium was heated automatically to 70 degrees F with electric cables, previous experiments (3) having shown this practice to be very beneficial in rooting blueberry hardwood cuttings in this locality. Sixteen sections were set with 100 cuttings of each of the Rubel and Jersey varieties. It was necessary to use 200 Rubel cuttings in each of the other four sections. The cuttings were set March 25. Three fertilizers were used, ammonium phosphate (11–48–0), tankage (6–10–0) and VHPF, a soluble compound said by the manufacturer to be a complete plant food equivalent to a 5–25–15 fertilizer plus vitamins, hormones and minor elements.

Fertilizer treatments were duplicated in frames with and without bottom heat. The three fertilizers were applied to certain sections at the time the cuttings were set and to the remaining sections after secondary shoot growth indicated that rooting had taken place. In the heated sections this was July 1, in the unheated July 22. The rates of application were 3 grams and 6 grams per square foot, which are

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equivalent to approximately 300 and 600 pounds per acre, respectively. The fertilizers were applied by hand, care being used to obtain uniform distribution. Immediately afterward the beds were watered by sprinkling. The cuttings were taken up and data were recorded October 24 to 28. The treatments and the results are shown in Tables I and II.

The data show that top growth on the cuttings was greatly stimulated by fertilizers, especially ammonium phosphate and VHPF. These fertilizers produced many plants with 12 to 24 inches of shoot growth and a few even larger. No detrimental effects of fertilizers was ob-

TABLE I—FERTILIZER RESPONSE OF BLUEBERRY HARDWOOD CUTTINGS ROOTED WITH BOTTOM HEAT — 100 CUTTINGS EACH LOT (INSERTED MARCH 25, 1947, EXAMINED OCTOBER 24–25, 1947)

Fertilizer Treatment	Date Applied	Variety	Rooting (Per Cent)		Shoot Length Per Rooted Cutting (Per Cent)			
			Good	Total	Over 18 Ins	12 to 18 Ins	6 to 12 Ins	Under 6 Ins
None—check		Jersey	94	97	—	—	29	71
		Rubel	92	94	—	—	42	58
Tankage	Jul 1	Jersey	84	90	—	5	46	49
3 gms/sq ft		Rubel	96	98	1	4	50	45
Tankage	Jul 1	Jersey	95	96	5	17	29	49
6 gms/sq ft		Rubel	95	97	1	13	53	33
11–48–0	Jul 1	Jersey	87	88	21	15	36	28
3 gms/sq ft		Rubel	99	99	5	32	51	12
11–48–0	Jul 1	Jersey	87	93	19	10	28	43
6 gms/sq ft		Rubel	93	94	7	21	56	16
VHPF	Jul 1	Jersey	86	87	5	9	48	38
3 gms/sq ft		Rubel	98	98	10	25	51	14
VHPF	Jul 1	Jersey	95	100	5	17	53	25
6 gms/sq ft		Rubel	93	95	14	30	36	20
11–48–0	Mar 25	Rubel						
3 gms/sq ft		(200)	86	86	15	37	36	12
VHPF	Mar 25	Jersey	81	81	2	14	49	35
3 gms/sq ft		Rubel	92	93	—	9	76	15
VHPF	Mar 25	Rubel						
6 gms/sq ft		(200)	81	81	6	12	63	19

TABLE II—FERTILIZER RESPONSE OF BLUEBERRY HARDWOOD CUTTINGS ROOTED WITHOUT BOTTOM HEAT — 100 CUTTINGS EACH LOT (INSERTED MARCH 25, 1947, EXAMINED OCTOBER 27–28, 1947)

Fertilizer Treatment	Date Applied	Variety	Rooting (Per Cent)		Shoot Length Per Rooted Cutting (Per Cent)			
			Good	Total	Over 18 Ins	12 to 18 Ins	6 to 12 Ins	Under 6 Ins
None—check		Jersey	75	86	—	—	51	49
		Rubel	74	93	—	2	48	50
Tankage	Jul 22	Jersey	70	93	—	6	40	54
3 gms/sq ft		Rubel	83	93	—	4	40	56
Tankage	Jul 22	Jersey	87	92	—	12	37	51
6 gms/sq ft		Rubel	79	95	—	9	34	57
11–48–0	Jul 22	Jersey	69	92	13	12	36	39
3 gms/sq ft		Rubel	76	92	7	12	41	40
11–48–0	Jul 22	Jersey	91	98	17	15	42	26
6 gms/sq ft		Rubel	84	95	6	16	45	33
VHPF	Jul 22	Jersey	82	91	2	17	51	30
3 gms/sq ft		Rubel	89	98	3	14	42	41
VHPF	Jul 22	Jersey	78	94	19	10	26	45
6 gms/sq ft		Rubel	84	91	5	10	44	41
11–48–0	Mar 25	Rubel						
3 gms/sq ft		(200)	80	90	1	20	51	28
VHPF	Mar 25	Jersey	77	91	3	12	42	43
3 gms/sq ft		Rubel	79	89	1	3	59	37
VHPF	Mar 25	Rubel						
6 gms/sq ft		(200)	65	75	3	6	43	48

served. Fig. 1 shows rooted cuttings fertilized with ammonium phosphate, 3 grams per square foot, in comparison with unfertilized cuttings. An attempt was made to select plants that would illustrate an approximate average of the response to both treatments.

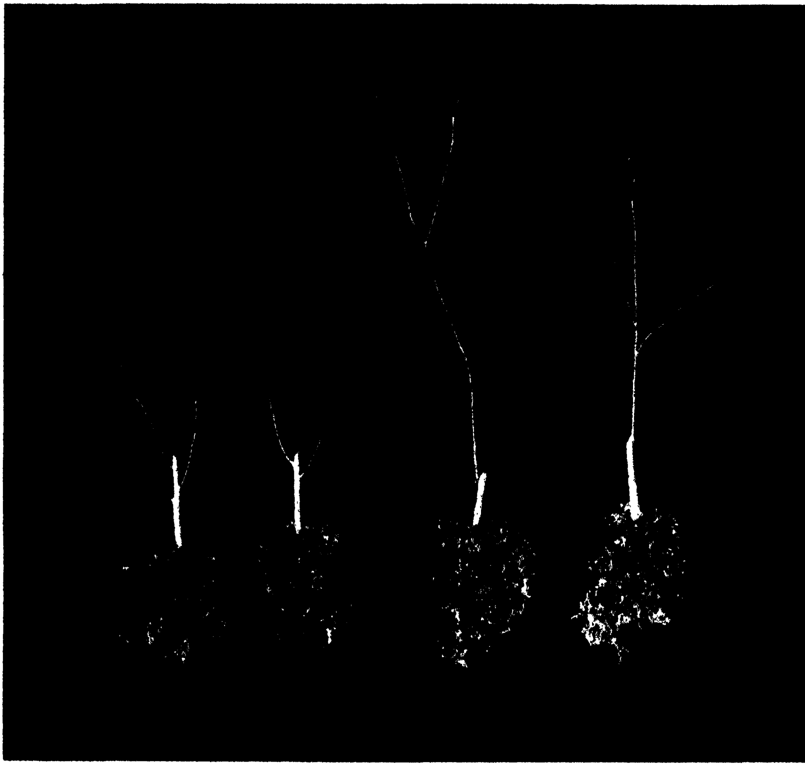

FIG. 1. Rubel hardwood cuttings rooted in sand-peat with bottom heat. Left: Not fertilized. Right: Fertilized after rooting with ammonium phosphate (11–48–0), 3 grams per square foot.

Tankage at 3 grams per square foot gave no increase over the check in the unheated frame and only slight increase in the heated frame. At 6 grams per square foot it gave better results but not equal to the growth obtained with soluble fertilizers. Ammonium phosphate produced as good results as VHPF, which is a much more expensive fertilizer if used at corresponding nitrogen levels.

Application of ammonium phosphate immediately after setting the cuttings was as satisfactory as application of like amounts after rooting had occurred. This probably indicates that suitable fertilizers may be applied at any time after setting the cuttings. Early application may be desirable because it is easier to apply dry fertilizers before leaves emerge. It is not impossible afterward, but care must be used to wash off immediately soluble fertilizers that adhere to the leaves.

In late October there were noticeable differences in maturity of the plants in the different plots, maturity being delayed progressively with increasing quantities of available nitrogen. In the plots fertilized with 6 grams of ammonium phosphate per square foot, the leaves were very large and deep green, shoots were relatively soft and the roots were noticeably less mature than in plots that received less nitrogen. At the 3-gram rate, almost as much top growth and slightly earlier maturity resulted. Very late maturity of tops and roots would be a disadvantage even in this region of mild fall and winter weather. It would interfere with fall digging of rooted cuttings, which is often desirable in commercial propagation.

A commercial propagator near Auburn, Washington applied ammonium sulfate 2 grams per square foot in 1947 with good results. This may mean that blueberry cuttings in peat require only nitrogen for maximum response.

Further work is planned to determine the importance of the source of nitrogen and the possible advantages of using other fertilizers. In the meantime, the application of ammonium phosphate, ammonium sulfate or any proven blueberry fertilizer at rates that will provide 30 pounds of actual nitrogen per acre, would seem to be advisable. This conclusion supports Doehlert's (1) recommendations.

In this experiment, bottom heat gave slightly higher percentages of large root systems but such good rooting occurred without bottom heat as to make the installation of heating cables a questionable expense. In previous experiments the benefits of bottom heat were more pronounced. The month of May was unusually warm in 1947, which probably accounts for the good results obtained this year without bottom heat.

Summary

The application of certain fertilizers resulted in a marked increase in shoot growth on blueberry hardwood cuttings without producing detrimental effects. Of the three fertilizers used, ammonium phosphate gave the most satisfactory response. The slower acting organic fertilizer, tankage, did not give as good results as were obtained with ammonium phosphate. A soluble compound containing minor as well as major plant food elements was not superior to ammonium phosphate. Though preliminary in nature, this experiment suggests the application of proven blueberry fertilizers to propagating beds by the time the cuttings are rooted at rates that would provide approximately 30 pounds of actual nitrogen per acre. Exact timing of the application did not appear to be important.

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Effect of Temperatures Above and Below Freezing on the Breaking of Rest in the Latham Raspberry[1]

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As a part of the raspberry hardiness investigations carried on at the University of Minnesota it was thought that it would be of interest to determine the effect, if any, of intensity of cold upon the breaking of the rest period in the Latham raspberry. By rest period is meant the period in the cycle of perennial plants when they will not grow, although conditions may be favorable for their growth. This is apart from dormancy when the growth of the plant is stopped because of unfavorable external conditions such as low temperature or lack of water.

The methods used in this study were adapted from the methods used by Brierley and Landon (1) to determine the length of rest in the Latham raspberry. Canes were cut in the field and were placed in containers with water just covering the butts of the canes. Care was taken to insure that no air got into the conducting vessels of the canes to interrupt the conduction of water upward. The canes were placed in a cool greenhouse and notes taken on their development to determine the depth or intensity of rest. This was indicated by the length of time required for the buds to begin to grow. The beginning of growth was recorded at the time the bud scales separated so the tip of the first true leaf could be seen on several buds on at least three of the four canes in a sample. It was considered that rest was broken when growth started in 9 days as later samples still required that length of time to begin growth.

In this study a large number of canes were cut October 14 and stored with their butts in water at 37.4 degrees F and 26.6 degrees F. The cold rooms in which the canes were stored were maintained within one degree of the stated temperature. Samples were taken from this storage on October 21 and 28 and thereafter at 2-day intervals. Notes were taken and the water changed in the containers every 2 days also.

A third lot of canes was collected October 21 and were held at temperatures alternating between 26.6 and 37.4 degrees F. It was held at the lower temperature for 8 hours and the higher temperature for 16 hours each day.

The results of these experiments may be seen in Fig. 1. Of the canes stored at 37.4 degrees F the first sample took 21 days for growth to start. The time required for growth to start gradually decreased through successive samples until after 37 days of exposure to this temperature rest was broken. From the second lot stored at 26.6 degrees F, however, the first sample did not start to grow until it had been 44 days in the greenhouse. Rest was not broken in this lot until the canes had been exposed to 26.6 degrees F for 41 days. The canes in the third lot exposed to alternating temperatures took longer to start and required a longer exposure to low temperature to break the rest than either of the lots exposed to constant low temperature.

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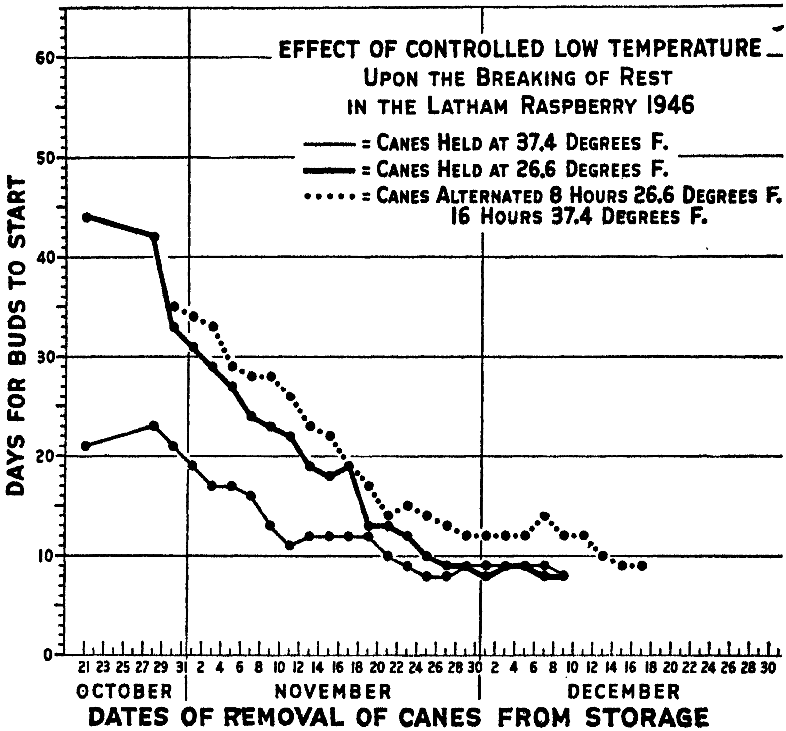

FIG. 1. Effects of controlled temperature on breaking the rest of Latham raspberries. 1946.

These results show that the effect of temperature below freezing was noticeable very soon after the canes had been exposed to these temperatures. In fact the initial effect of the below freezing temperatures seemed to be the most important in retarding the breaking of rest. On October 21, after the canes had been held in storage for a week the sample held at 26.6 degrees F required 23 days longer for growth to start than the sample held at 37.4 degrees F. On the other hand, on November 23, when rest was broken in the lot stored at 37.4 degrees F, there was only a difference of 3 days in the times required for growth to start in the two lots. Rest was broken in the lot stored at the lower temperature 4 days later. As the two curves tended to converge, it appeared that after the initial setback due to the low temperature, rest was broken at least as fast at below freezing temperatures. In other words, the effect of below freezing temperature on the canes stored at 26.6 degrees F was an initial check after which rest was broken as fast or faster than at higher temperatures. This initial effect of below freezing temperature tends to explain why canes exposed to alternating temperatures required more cold to break their rest.

The total number of hours of cold necessary to break the rest in the

Latham raspberry has been calculated from data recorded by Brierley and Landon (1) for the years 1943 to 1945 and by the author for 1946. It was found that an average of 1,405 hours at a temperature of 45 degrees F and below was required to break the rest. In the present experiment, however, in the lot held at 37.4 degrees F only 1,107 hours were required to break the rest, including hours of low temperature to which the canes were exposed in the field before they were collected. The lot held at 26.6 degrees F required 1,251 hours of cold to break the rest and the lot which received the alternating treatment required 1,470 hours. This latter figure is greater than the average required by canes whose rest was broken normally in the field but outside temperatures as a rule do not fluctuate as frequently above and below 32 degrees F as was the case in this treatment. Table I shows that rest

TABLE I—MEAN FIELD TEMPERATURES FROM THE DATE OF THE FIRST FROST TO THE DATE ON WHICH REST PERIOD OF LATHAM RASPBERRY WAS BROKEN AND TOTAL HOURS BELOW 46 DEGREES F REQUIRED TO BREAK REST

Year	Mean Temperature (Degrees F)	Total Hours
1943	30.93	1,646
1944	36.63	1,323
1945	35.22	1,476
1946	38.15	1,186

was broken more rapidly in seasons when the mean temperature was greater than in falls and early winters when it was less. When the mean temperature for the period from the time of the first frost until the date on which rest was considered to be broken was low, the number of hours at 45 degrees F or below required to break rest was great. Although there is not a direct relationship between this mean temperature and the number of hours required to break the rest, it lends support to the conclusion that temperatures between 45 and 32 degrees F do break rest faster than below freezing temperatures. The results agree with those of Chandler *et al* (2) who observed that rest was broken as rapidly at temperatures above 32 degrees F as at lower temperatures.

This experiment shows that rest is broken more rapidly by temperatures between 45 degrees and 32 degrees F than at sub-freezing temperatures. The retarding effect of sub-freezing temperatures appears to be due to an initial shock effect of such temperatures as continued exposure to sub-freezing temperatures breaks rest rapidly.

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Preliminary Report of an Informal Cooperative Study of Rest in the Latham Raspberry

By W. G. BRIERLEY, *University of Minnesota, St. Paul, Minn.*

IN 1946 the writer suggested to several workers in the region extending from the lower Mississippi Valley to the Canadian Great Plains that a cooperative study of rest in the Latham raspberry would be of considerable interest to those studying the winter behavior of the raspberry. At that time it seemed possible that length of growing season in its relation to time of bud formation might have an effect upon onset, intensity and duration of rest. This possibility was suggested by the difference in behavior of the Latham variety relative to breaking of rest at Duluth compared to St. Paul and points to the south.

Several workers recorded data at their home stations during the fall and winter of 1946–1947. These data, recorded by the several cooperators, have been combined in this report and are shown in Fig. 1. The method commonly followed in similar studies was used in all cases. Samples of canes were cut in the field on the dates shown in Fig. 1. The butts were placed in water immediately to avoid entrance of air into conducting vessels. They then were placed in a cool greenhouse, or under comparable conditions. Water was changed frequently and only enough used to keep the butts covered. At frequent intervals

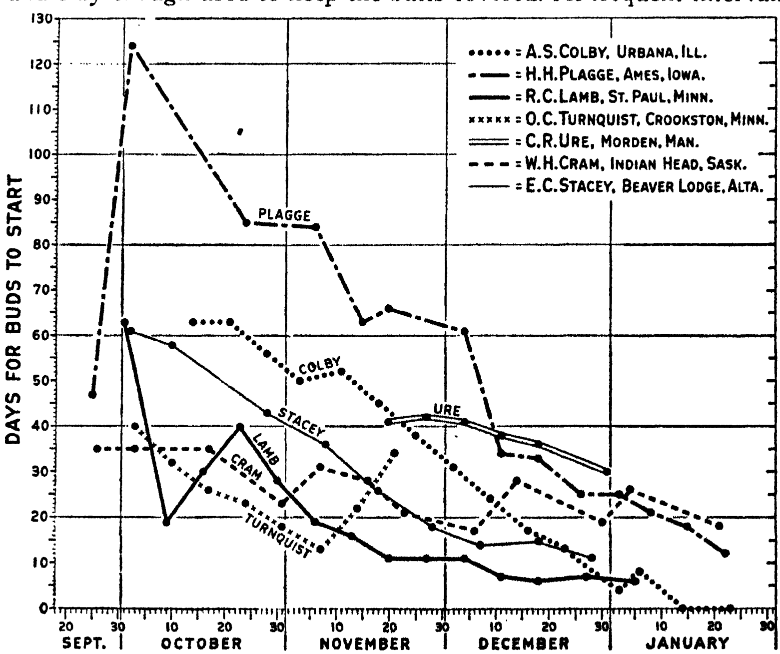

FIG. 1. Rest period in the Latham raspberry as recorded at seven stations in the regions extending from Urbana, Illinois to Beaver Lodge, Alberta, 1946–1947. Curves show number of days in greenhouse for buds to start on samples collected at places and dates shown.

a short piece was cut from the butts to avoid plugging of the vessels by bacteria or other organisms. The number of days required for bud activity to be evidenced for all locations and samples is shown in Fig. 1.

It is obvious from this composite graph that length of growing season had little effect upon rest. The patterns of onset and decline are similar for all localities, but intensity varied. Turnquist and Cram recorded low intensity in northern localities and Plagge in Iowa recorded very high intensity, but the other curves show no consistent relationship between intensity and locality.

The time when rest was broken, as shown by Lamb at St. Paul, followed consistently the pattern shown previously by Brierley and Landon (2). In that locality, as indicated by bud activity under greenhouse conditions, rest was ended by mid-December. But a noticeably later breaking was recorded by both Plagge in Iowa and Cram in Saskatchewan with the data recorded by Ure in Manitoba showing the same trend. It is apparent from the graph that rest behavior in the Latham raspberry is far from uniform over the range from south to north.

An interesting peculiarity in the rest pattern can be seen clearly in the data obtained by Lamb at St. Paul, Minnesota, and Turnquist at Crookstone, Minnesota. In these cases there was a definite increase in intensity after decline had begun or was well under way. Lamb found an increase of 21 days in mid-October and Turnquist reported a similar increase in mid-November. Cram found that a lesser increase in intensity occurred in November, December, and again in January. Minor fluctuations in intensity presumably may be due to sampling or to varying conditions in the greenhouse, but it seems likely that the more marked increases were due to some other factor.

Another peculiarity was reported by some workers. Cane samples collected in September or early October failed to show bud activity at any time in the greenhouse although in most cases the canes appeared to be in good condition. The cause of this failure of the buds to develop has not been determined.

Still another peculiarity was reported by some workers. Samples collected on relatively early dates showed bud activity within 15 to 30 days in the greenhouse. This activity was evidenced by swelling of the buds, separation of the bud scales, and a slight development of the shoot sufficient to show some green at the bud tip. Development was arrested at that stage for varying lengths of time and in some cases no further development occurred. This unexplained behavior has at times made it difficult to determine definitely the time when rest was ended.

The data obtained by Colby in Illinois are of special interest in relation to winter injury. In this case buds were found to be active and green at the tips in the field in mid-January. As injury due to cold following such activity has been noted by Brierley (1) and Vaile (3), it seems not unlikely that such out-of-season bud activity may, at times, be a major cause of winter injury throughout raspberry growing areas.

As the results obtained were interesting and as some who intended to cooperate were unable to do so during 1946–47, the study is being repeated during the present season.

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Nutrient-Element Balance: Application of the Concept to the Interpretation of Foliar Analysis

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The mineral composition of leaves is coming to be accepted as a valid criterion of the nutritional status and fertilizer requirement of the plant. There is, however, at the present time, little uniformity in the methods of approach to the problem of the most logical means of interpreting foliar analysis. In the authors' opinion this situation stems from the lack of a generally accepted basic concept of exactly what is embraced in the term "nutritional status of the plant". This is readily understandable when one considers the number of factors and the complexity of interactions which contribute to the mineral composition of leaves and the relatively meager information which has so far been accumulated upon which to formulate a sound basis for the interpretation of leaf analysis.

Some 15 elements have been demonstrated to be essential for the normal growth and reproduction of plants. If each of these elements has a specific function in the life processes of the plant it is evident that these processes cannot proceed at the optimum rate unless all of these elements are present in the proper amounts and proportions. It follows, then, that the term "nutritional status of the plant" must embrace the consideration of all of the essential elements present in the leaf; and, since nonessential elements, if present in the nutrient medium, will be absorbed to varying degrees and consequently affect the absorption and function of all other elements, the influence of these nonessential elements, when present, must also be considered. Because plant species differ with respect to growth rate, proportion of various tissues produced, amount and proportion of the types of stored foods elaborated, and in many other ways, their requirements for the various nutrient elements differ. Thus, it is apparent that the optimum nutritional status of each crop as reflected by leaf analysis will differ, and standards of comparisons must be set up for each crop. This fact, however, does not invalidate the principles upon which the interpretation of foliar analysis must be based. These principles undoubtedly have general application, even though the methods of technique of attack may be different with different plants.

It has long been known that the absorption and accumulation of each nutrient ion is dependent on the absorption and accumulation of every other available ion. The differential rate of absorption and the differential intensity of the depressing effect of one ion upon the absorption of other ions, depending upon the charge, relative size, and activity of the ions involved, have also been recognized, though very incompletely understood. That the absolute concentration of an element in the leaf is not a logical measure of its functional concentration has not been so generally appreciated. Evidence is rapidly accumulating which shows that in order to carry out properly its normal function in the plant, each essential element must occur in the leaf in the proper proportion to every other essential element. It is to this phase of the problem of

the interpretation of leaf analyses that the concept of nutrient-element balance is applicable.

The basic principles involved in the concept have been developed from observations and data obtained from nutritional experiments on tung trees (*Aleurites fordii* Hemsl.) grown in sand cultures, and from corroborative evidence supplied from fertilizer experiments carried on in the field by co-workers. That the concept is applicable to other plants is amply demonstrated by results reported in the literature by numerous workers in the field of plant nutrition.

The main thesis involved in the concept of nutrient-element balance may be simply stated as follows: All other factors being constant, plant growth and symptom expression are functions of the two variables of nutrition, intensity and balance, as they are reflected in the composition of comparable leaves sampled when the plants are in the same stages of growth or development. At any level of nutritional intensity (total equivalent concentration of all functional nutrient elements in the leaf) there exists an optimum balance or proportion among these elements at which maximum growth for that intensity level will result. The maximum potential growth and yield for any given plant, however, will be obtained only when the proper balance between all of the nutrient elements occurs in combination with their optimum intensity.

It should be emphasized that neither high intensity nor proper balance alone will result in maximum growth and yield. Though a high yield is dependent upon a sufficiently high intensity, a high level of nutritional intensity cannot result in maximum growth and yield unless a proper balance exists between all of the elements. It is because of this that it is possible to have completely normal-appearing, yet low-yielding plants. Such plants occur when conditions of proper balance are present at a low level of nutritional intensity. Under these conditions it is probable that all vital processes within the plant are able to take place in the normal relation to one another, but that the rates of all these processes are equally reduced by the low intensity of nutrition. Hence, the lack of all symptoms of malnutrition in no way indicates the existence of optimum nutritional status in the plant.

It is equally as true that the appearance of a symptom "typical" of the "deficiency" of a certain element does not indicate that a low level of that element in the plant is necessarily responsible for the symptom. It indicates, only, that that element is low in relation to some one or more other essential elements and cannot, therefore, fulfill its normal function adequately at the high metabolic rate brought about by the relatively high level of the other element or elements. It follows that only through complete leaf analysis is it possible to determine, for example, whether "magnesium deficiency" symptoms are due to a low level of magnesium nutrition, or to too high a level of calcium or potassium or nitrogen, or to some combination of these factors or possibly others. The necessity of complete leaf analysis is further emphasized by the fact that, in tung at least, the leaf symptoms expressed by the "deficiency" of a certain element vary, depending on the element or elements whose *excess* is responsible for the occurrence of the symptom.

For these reasons, even complete leaf analysis alone can give only a part of the picture of the nutritional status of the plant and must always be correlated with symptom expressions or growth or yield responses in order to be intelligibly interpreted.

At the present stage in our knowledge it would be futile to attempt to set up specific standards of optimum balance and intensity. This will be possible only when sufficient carefully controlled experiments have been carried out on each crop plant to enable us to determine accurately the maximum potential economic yield for each crop and the leaf composition which is correlated with that response. It would seem that one of the most significant contributions that physiologists and soil scientists could make in the field of crop production should come from concerted efforts towards determining the factors that influence leaf composition and setting up such standards.

In order to better visualize some of the complex interactions that must be considered in interpreting foliar analysis and to see how these interactions can be determined through properly designed factorial experiments, let us consider a few examples. The following data were obtained from a sand culture experiment with tung trees involving all possible combinations of three rather widely different levels each of potassium, magnesium, and calcium. As far as was possible the supply of all other elements was held constant.

Relationships between boron and the bases potassium and calcium have been reported by a number of workers. The influence of magnesium on boron nutrition, as far as the authors are aware, has not been mentioned. During the course of this experiment, in which boron was uniformly supplied at the rate of 0.1 ppm, one of the first leaf symptoms to appear was one that has been consistently associated with an excess of boron in the nutrient medium. The symptom was graded on the basis of increasing severity on a scale of 1 to 6. Though it was evident at the time of grading that the severity of the symptom was inversely correlated with the level of magnesium supply, when leaf analyses were obtained no correlation could be found between magnesium content of the leaf and the severity of the boron toxicity symptom. Neither was there any correlation between the boron content of the leaf and the severity of the symptom. However, when the ratio of magnesium to boron in the leaf was plotted against the boron toxicity grade it was immediately apparent that, regardless of absolute concentration of either boron or magnesium, the severity of the symptom was closely correlated with the magnesium: boron ratio (Fig. 1). That there is a close relationship between magnesium and boron nutrition has been corroborated in field experiments with tung in which it has been found that the oil content of the fruit was significantly increased by boron applications. This beneficial effect of boron was nullified, however, by applications of magnesium in the form of magnesium sulfate.

In the previously mentioned sand culture experiment it was noted also that at the lower levels of the three bases, particularly of potassium, symptoms appeared which had previously been produced only under conditions of excessive manganese supply, while at the high

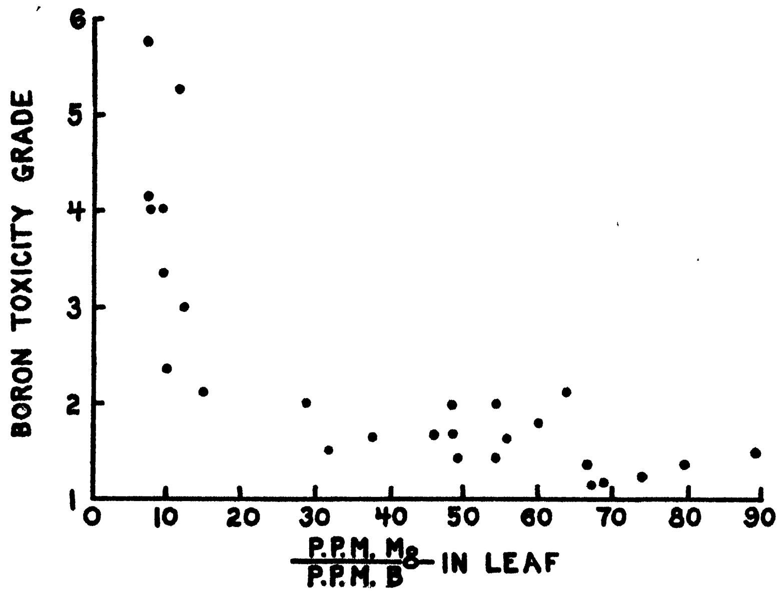

FIG. 1. Relationship between the severity of boron toxicity symptoms and the magnesium: boron ratio in the leaves of tung trees supplied with solutions having various potassium: magnesium: calcium ratios.

levels of the bases symptoms generally associated with manganese deficiency appeared. This was true even though manganese was uniformly supplied at the rate of 8 ppm. This response was explained by leaf analysis which showed an inverse relationship to exist between potassium and manganese content of the leaves (Fig. 2A). The curves in this figure connect points obtained from leaf analysis data from plants receiving increasing levels of potassium supply. By comparing those curves representing analyses of leaves from plants receiving low, intermediate and high levels of magnesium supply the effects of varying levels of magnesium supply on accumulation of both potassium and manganese may be observed. Such a comparison shows that at the same levels of potassium and calcium, increasing magnesium supply (which, in every case, resulted in increased magnesium accumulation) reduced the accumulation of potassium, while with one insignificant exception, the first increment of magnesium resulted in an increased manganese accumulation and the second increment brought about a reduced accumulation of manganese.

A similar comparison of those curves representing analyses of leaves from plants receiving low, intermediate and high levels of calcium (designated L, I, and H, respectively) shows that, at the same levels of potassium and magnesium supply, increasing calcium supply (which, in every case, resulted in increased calcium accumulation) resulted, with one insignificant exception, in a decreased potassium accumulation with the first calcium increment and an increased potassium accumulation with the second calcium increment. With the ex-

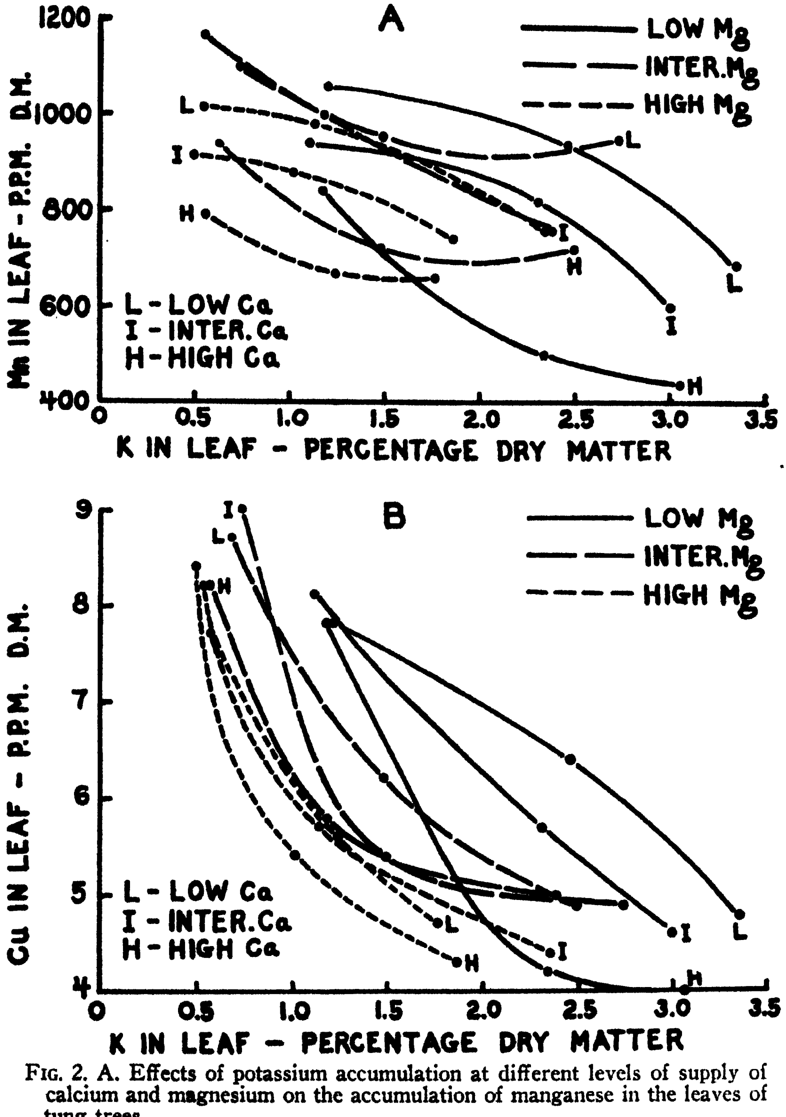

FIG. 2. A. Effects of potassium accumulation at different levels of supply of calcium and magnesium on the accumulation of manganese in the leaves of tung trees.
B. Effects of potassium accumulation at different levels of supply of calcium and magnesium on the accumulation of copper in the leaves of tung trees.

ception of the intermediate levels of magnesium supply at the low and intermediate levels of potassium supply, increased calcium supply and accumulation resulted in decreased manganese accumulation.

The data represented in this figure, thus, not only indicate the pronounced effect of potassium accumulation on that of manganese, but also show that this effect is also produced, though to a lesser degree,

by calcium and magnesium. They further show that the depressing effect of each of these elements on manganese accumulation is not a function of the absolute concentration of any one of these elements alone, but depends upon the total and the proportion in which the three are accumulated. Some factor or factors as yet undetermined, other than level of calcium, magnesium, potassium and manganese in the leaf, must have contributed also the appearance of manganese deficiency symptoms under the conditions of this experiment, since the levels of manganese in the leaves showing apparent manganese deficiency symptoms were far in excess of levels that have proved adequate to prevent the appearance of these symptoms in other experiments.

The depressing effect of the major bases, particularly potassium, on the accumulation of the heavy metals is further illustrated by the inverse relationship between potassium and copper accumulation (Fig. 2B) obtained in this same experiment. The observations already made regarding the effects of the interactions between calcium, magnesium, and potassium on manganese accumulation also apply, though to a lesser extent, to copper accumulation.

Though analyses for zinc have not yet been obtained on the material from this experiment, growth data and leaf symptoms would indicate that a similar relationship may exist between potassium and zinc.

These interactions between the major bases and the essential heavy metals may be of considerable economic importance in view of the recent reports of substantial increases in yield which have resulted from the application of such elements as manganese and zinc to a variety of crops, even in cases where no symptoms of deficiencies were apparent.

Since increased potassium evidently not only decreases the accumulation of the heavy metals, but also increases their level of requirement, it might be well to consider the possibility of a deficiency of these elements in plants having a high level of potassium nutrition.

That the competitive effects between the bases and the heavy metals are not all one-way phenomena in favor of the bases is illustrated by the depressing effect of manganese accumulation on that of calcium (Fig. 3). These data were obtained from analyses of leaves from a sand culture experiment on tung which involved varying ratios in the supply of iron to manganese. It may be well to point out that the range of levels of manganese found in these leaves as well as that shown in Fig. 2 is well within the extremes often found in tung leaves from field-grown trees showing so apparent symptoms of malnutrition.

Considerable work has been done in attempts to correlate the nitrogen content of leaves and the nutritional status of the plant with respect to that element. Here again the consideration of one element by itself may lead to erroneous conclusions. The evidence accumulated from work on tung indicates that the supply of elements other than nitrogen may be more effective in altering the nitrogen content of the leaf than the supply of nitrogen itself. It is often stated that nitrogen is the most important element in limiting plant growth. If by this it is meant that in the absence of sufficient nitrogen maximum growth cannot result even though the level of other elements is adequate, the state-

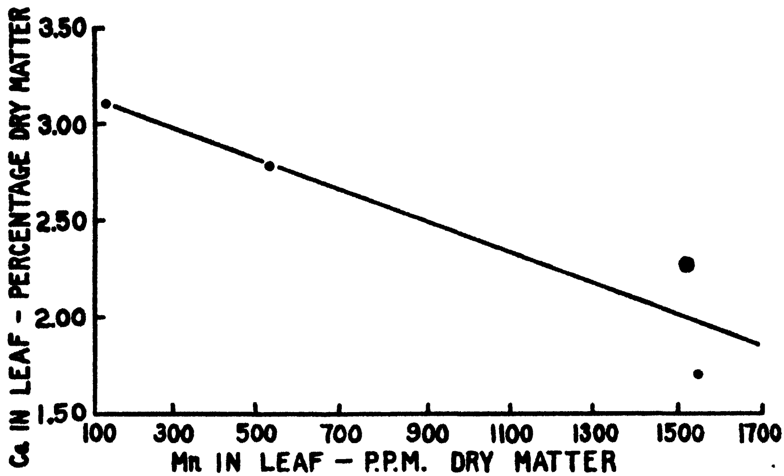

FIG. 3. Reduced accumulation of calcium resulting from increased manganese accumulation in the leaves of tung trees.

ment is true. This, however, is also true with respect to all of the other essential elements. When other elements are available in adequate supply and correct balance, increased nitrogen supply is usually reflected by the plant in increased growth while the nitrogen content of the leaves may be affected only slightly. Nitrogen accumulation probably takes place only when a functional unbalance exists between nitrogen and some other element. Analyses of tung leaves taken from trees grown in sand cultures supplied with nutrient solutions having nitrogen concentrations of 9, 27, 81, and 162 ppm, showed the following respective nitrogen content in percentage of dry matter: 2.58, 2.53, 2.67, and 2.90. In contrast to this slight effect on nitrogen content of wide differences in nitrogen supply, when nitrogen supply was kept constant at 81 ppm, and phosphorus was supplied at levels of 0, 3, and 9 ppm, the nitrogen content of the leaves in percentage of dry matter was 1.91, 2.67, and 3.17, respectively.

The effects of other elements on nitrogen accumulation and the lack of correlation between the level of nitrogen supply and the percentage of nitrogen in the leaf do not preclude the use of data on nitrogen content in the interpretation of leaf analyses. They only further point out the necessity of considering any significant change in level of leaf nitrogen, as is true with the mineral elements, in terms of the over-all nutritional status of the plant rather than in terms of one or a few elements. Leaf analyses showing unusually high or low nitrogen content should immediately direct attention towards the determination of the nutritional unbalance responsible for the situation.

The examples of competitive effects that have been given involve elements that normally occur in the substrate in the form of cations. However, because the cation: anion ratio within the leaf is a constant, the accumulation of ions of either charge must be accompanied by an equivalent accumulation of ions of the opposite charge. Therefore, the

absolute level of ions of both charges may be either increased or decreased by conditions that promote the accumulation of one or more ions of either charge.

Evaluation of the complex cation: anion interactions cannot be made on the basis of mineral analyses of leaves, however, since the ions available to the plant through the nutrient medium do not alone control the charge and quantity of ions available within the plant for exchange phenomena. Hydrogen, hydroxyl, and carbonate ions as well as complex organic ions resulting from metabolic processes within the plant enter into the cation: anion balance, and relationships of these to the mineral composition of leaves can only be determined through fundamental biochemical studies.

The importance of taking into consideration in the interpretation of foliar analysis the effects that varying supplies of the nutrient elements may have on the absorption and accumulation of one another cannot be over-emphasized. The significance of any given leaf composition surely cannot be evaluated intelligently unless the interactions between the elements contributing to that composition are understood and considered. It seems even more obvious that to attempt to alter the nutritional status of a plant without allowing for the interactions that will take place between the element or elements applied and those already available to or present in the plant may be futile. From the examples already given it is apparent that such a procedure may fail not only to produce a beneficial response, but may result in reduced growth or yield through bringing about a less favorable nutritional balance within the plant.

Probably only a few of the factors controlling the mineral composition of leaves are known, and certainly only a few of the many possible interactions between these factors are recognized. The few examples discussed here may serve a purpose if they do no more than emphasize the complexity of the problem of the interpretation of foliar analysis. Certainly a realization of the complexity of the problem should contribute to its ultimate solution. This can be true, however, only if it stimulates workers to organize a united and concerted program having a sound fundamental basis and aimed toward the simplification of the problem through a more complete understanding of the many factors involved.

Even though the interactions so far determined to exist between various elements may appear to be isolated and unrelated phenomena, it must be remembered that this is because they represent only a small part of the whole picture. If workers in this field can agree on a similar approach to the solution of the various problems and so coordinate their procedures that all the results obtained can be integrated, the physicochemical laws that control the accumulation of ions within the leaf as well as those that control their utilization in growth should be more fully understood. When this point is reached it should be possible not only to simplify the interpretation of foliar analysis in terms of the current nutritional status of the plant, but also to be able to predict with reasonable accuracy the response of that plant to any given fertilizer treatment.

Responses of Some Plants to DDT, Hexaethyl Tetraphosphate, and Parathion Applied as Aerosols

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INSECTICIDAL aerosols produced by the liquefied-gas method were first tested against mosquitoes and house flies in 1941 (Goodhue 5, Sullivan *et al* 18). This method of dispensing insecticides was extensively used in combat areas during the war and since then has been widely used against household pests. Recently the method has been employed with outstanding success in greenhouses to apply DDT, hexaethyl tetraphosphate, and parathion for the control of thrips, spider mites and many other pests. The purpose of this paper is to discuss the responses of plants in greenhouses to these three insecticides when applied in the form of gas-propelled aerosols. Some of the results are of experiments conducted from 1944 to 1947 at Beltsville, Maryland, but many of them are taken from commercial applications made by greenhouse men in other parts of Maryland and in Pennsylvania and Connecticut.

The solution of the insecticide in the liquefied gas is contained in a pressure cylinder and the insecticide is released into the atmosphere through a small orifice so that it is dispersed as a fine mist. The method of dispersing gas-propelled aerosols is covered in a patent issued to Goodhue and Sullivan (8) and assigned to the Secretary of Agriculture.

Although by far the greatest use for the aerosol method has been for dispensing insecticides in treating plants, other uses have been reported. Clayton (3) obtained excellent control of blue mold on tobacco with an aerosol containing benzyl salicylate in cottonseed oil. This aerosol has been made available commercially and was extensively used on tobacco seedbeds during 1947. Hamner *et al* (9), using beta-naphthoxyacetic acid, and Zimmerman and Hitchcock (19), using various substances in aerosols, induced epinasty and parthenocarpic fruit set in tomatoes. McKay *et al* (11) produced polyploidy by applying colchicine in aerosols to plants. Goodhue and McGovran (6) demonstrated that bacterial activity could be reduced by dispersing the germicides propylene glycol and hexyresorcinol in liquefied-gas aerosols.

Insecticidal aerosols on field crops have been tested most extensively against the pea aphid (4). Of the insecticides used in this way DDT was the most effective. Special light-weight dispensers constructed for attachment to a tractor or truck were capable of treating over 100 acres per day, with resultant good commercial control and significant crop increases. More than 25 other vegetable-crop pests were found susceptible to DDT aerosols (13). Among the pests more successfully controlled by aerosols than by other methods were the eggplant lacebug (12) and the six-spotted leafhopper, which is the vector of aster yellows in lettuce (F. F. Smith and Ross Thompson in unpublished experiments). Potato insects are easily killed by DDT aerosols (2),

but since no effective fungicide was found that could be incorporated into the aerosol solution, fungicides had to be applied separately.

In early tests on greenhouse plants, nicotine in a liquefied-gas aerosol was found to be twice as effective against the green peach aphid as in smoke from combustible powder in a pressure can (16); Lorol thiocyanate[1] was equally effective against cyclamen mites when applied in aerosols and sprays (7), and DDT aerosols were effective against thrips, whitefly adults, certain aphids, the American roach, ants, crickets, the greenhouse leaf tier, the azalea leaf miner, the rose midge, the chrysanthemum midge, fungus gnats, centipedes, sowbugs, and the broad mite (Smith and Goodhue 17, Smith *et al* 14). Many of these pests have disappeared from greenhouses following the use of DDT aerosols.

During the past year hexaethyl tetraphosphate, containing 21 per cent tetraethyl pyrophosphate, in aerosols was shown to be toxic to the active stages of the two-spotted spider mite or red spider, nine species of aphids, whitefly adults, and the Mexican mealybug (15). The effectiveness of this chemical created considerable interest among florists, and in aerosols it offered a rapid method of applying control measures for the spider mites particularly on roses and carnations. In more recent tests parathion (O, O-diethyl O-*p*-nitrophenyl thiophosphate) in aerosols was very toxic to all pests affected by the DDT and hexaethyl tetraphosphate aerosols. The material is slowly volatile, and the residue continues, for several days to more than 3 weeks according to the dosage, to exercise a fumigating action against aphids, spider mites, and thrips.

In greenhouses the aerosols are dispensed from cylinders holding 4 pounds or more of solution, through a hose and short spray rod terminated by an oil-burner nozzle. The application is rapid, requiring only 4 seconds per 1000 cubic feet of space. The distribution of the insecticide is aided by turbulence of the expanding gas and by convection currents, so that smaller dosages can be used than by other methods. Precautions to safeguard the operator in handling the aerosol ingredients and in treating greenhouses have been published (15).

In tests with DDT aerosols on more than 150 kinds of plants in commercial or experimental greenhouses, injury to flowers or foliage was noted only in kalanchoe and cucumber. On kalanchoe epinasty and necrosis developed after about 10 days and progressed until most of the plant was killed to the ground. On cucumber slight bleaching or yellowish mottling developed following application of a DDT aerosol containing cyclohexanone. This injury was practically eliminated when a methylated naphthalene was substituted for the cyclohexanone. In one range with 28 acres of cucumbers under glass, two successive crops have been treated with marked increase in growth and in quality and quantity of fruits following destruction of thrips.

Among more than 180 kinds of plants treated with hexaethyl tetraphosphate aerosols, tomato and certain varieties of chrysanthemum — 30 out of 140 varieties tested — were the only plants found to be injured (15). Young tomato plants were more susceptible than older

[1]A proprietary product containing principally lauryl thiocyanate.

ones, and the susceptible varieties of chrysanthemum were more seriously injured when the growth was succulent. Injury to tomatoes appeared in 24 hours as small water-soaked spots, which later became necrotic. Injury to chrysanthemum was first recognized as scattered black dots, which became surrounded by a pale halo. Part or all of the leaf turned yellow with black dots. Brown spots appeared in the flowers of sensitive varieties.

Occasional reports have been received of burning of flowers and young leaves on rose and carnation or of the spotting, yellowing, and dropping of older leaves on roses. Certain of those injuries investigated by the writers appeared to follow excessive dosages of aerosol, or treatment at too high temperature, or a combination of the two. On roses leaf burning, yellowing, and abscission followed removal of shading from the glass and the recurrence of hot weather, these effects being more severe on the varieties Brandywine and Golden Rapture than Better Times. Since syringing for spider mite control is no longer practiced on greenhouse roses where mite control is efficient, the black spot disease has ceased to be a problem there, but powdery mildew has become more serious and still requires special control measures (10).

In five greenhouse ranges in three States, rose plants occupying slightly more than 1,100,000 square feet of space have been treated weekly or bi-weekly since January 1947 with hexaethyl tetraphosphate aerosols. All treatments have been made by the writers or by men trained to follow their instructions. No flower fading, such as is caused by azobenzene, or any abnormal burning, yellowing, or abscission of foliage developed. Until November no increase in the number of atrophied or deformed flowers, termed "bullheads" by the growers, has occurred on roses, such as was reported from various States (1) or observed by the writers after the application of this insecticide in sprays or fog machine. More recently a few "bullheads" and deformed leaves have occurred on Briarcliffe and Starlight where aerosols were being used. A marked increase in vigor of growth followed the elimination of spider mites by this aerosol. The treated plants produced larger leaves with a deeper green color, longer and heavier stems, and more flowers. New foliage and shoots developed from the lower stems and, following cutting back in July and August, vigorous new shoots attained desired stem length and produced flowers without the usual pinching. As a result the plants were scarcely out of crop in 1947.

In one of four ranges[2] of 12,000 rose plants 100,000 more blooms were cut during the first 8 months of 1947 than in the same period in 1946, and the stem length was 3 to 6 inches greater. In a second range roses cut for the first 7 months of 1947 equaled the crop for the entire year 1946. In a third range the numbers of roses cut during the summer (July to September), when spider mite injury is usually most severe, were as follows:

[2]The following florists cooperated by furnishing production records. A Gude and Sons, Rockville, Maryland; Gude Brothers, Laurel, Maryland; Thomas Boyer, Towson, Maryland; and J. H. Thompson and Sons, Kennett Square, Pennsylvania.

Variety	1946	1947
Better Times	51,727	222,945
Golden Rapture	5,768	25,903
Pink Bountiful	1,356	23,482
Talisman	5,629	27,286
Xmas Beauty	0	22,139
Total 14 varieties	84,240	385,733

In a fourth range containing 40,000 rose plants azobenzene was used in November 1946, but mite infestation had again become severe by January 1947, when the aerosol treatments were started. Production records for this range were as follows:

Month	1946	1947
January	36,887	56,475
February	29,417	37,600
March	41,610	71,850
April	54,460	82,350
May	75,129	83,470
June	54,064	91,175
July	40,000	125,750
August	28,300	120,275
September	33,550	128,100
October	71,625	108,775
November	45,350	93,128
December	64,250	79,466

The stem lengths of cut roses in one 30-day period were as follows:

Stem Length (Inches)	Number of Roses	
	1946	1947
9	18,725	6,975
12	11,750	10,175
15	4,175	17,400
18	500	13,050
21	0	2,975
24	0	675

The improved growth of roses following control of spider mites by hexaethyl tetraphosphate aerosols has been so striking as to suggest some stimulatory action beyond the mere elimination of injury by this pest.

It should be noted that the more striking increases in production following the use of hexaethyl tetraphosphate aerosols take place during the summer months. It is during these summer months that spider mites become most numerous and most damaging. Attempts to control them by syringing and by application of aqueous spray materials favored blackspot. It was common to see the lower stems of roses bare of leaves as a result of spider damage, blackspot, and syringing. When the aerosol affords effective control of spider mite, without stunting or hardening of growth as occurred with older pesticides, and water is no longer applied to leaves, blackspot also disappears. It is then that roses approach their potential of summer production, and it is only then that the damage due to spider mites and to blackspot is fully visualized.

No other changes in cultural practices were introduced except those required to take advantage of the sustained increase in growth and flower production.

Similar improvement in appearance and in flower production of carnations was apparent in three ranges totaling about 220,000 square feet of glass, but comparative production records were not available.

In tests with parathion no direct injury has resulted on more than 50 commercial greenhouse crops, including tomato and 99 varieties of chrysanthemum except the variety Debonair. New growth developing after destruction of mites has been normal in appearance. It is still too early to determine whether sustained increases in growth will follow use of this material as in the case of hexaethyl tetraphosphate.

Although the insecticidal aerosols will doubtless be most useful to the commercial florists in pest control, research workers may find them helpful in destroying plant pests on experimental material. In the writers' experience with virus diseases in greenhouses, injury by spider mites has often interfered with plant growth and with the detection of symptoms. Elimination of mites by regular applications of hexaethyl tetraphosphate has permitted full expression of virus symptoms. The rapid decomposition of hexaethyl tetraphosphate has left no toxic residues to interfere with insect vector studies. In lettuce-breeding work conducted by Ross Thompson at Beltsville, Maryland, heavy infestations of spider mites threatened the destruction of plants in bud. Plants in one house that were treated with azobenzene failed to set seed, while in two other houses sister plants treated with hexaethyl tetraphosphate and parathion developed normal seed heads. Mr. Thompson had observed for some time the deleterious effect of azobenzene on the primordia, both in the inflorescence and in the vegetative growth of lettuce.

The ease of application of insecticidal aerosols and their high toxicity should be conducive to more efficient pest control in greenhouses.

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Important Problems in Vegetable Breeding

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OVER a considerable period of time the general problems confronting the vegetable breeder, such as hardiness, market quality, and disease resistance, remain relatively constant, while the specific problems may change very rapidly. As our fundamental sciences develop there arise possibilities for the solution of specific vegetable breeding problems that previously could not have been undertaken.

During World War II most fundamental research problems were neglected in favor of practical problems of immediate importance. I think most of us would agree that for the period of emergency this was desirable, but unless the balance between fundamental and applied research is soon restored both fundamental and applied research will be retarded. Among the problems confronting all plant breeders are those of adequate fundamental research in botany, plant physiology, genetics, plant pathology, biometry, chemistry, physics, entomology, meterology, and soils.

For instance, it is quite possible that adequate genetic research on the physiological problems involved in yield or in drought and cold resistance in vegetables could materially alter the breeding program. Research in soils may call for greatly different types of plants for adaptation to certain soils with specific fertilizing and irrigation practices. It is also possible that advances in the social sciences could have a great influence on plant breeding programs. In this connection I am thinking specifically of breeding of vegetable crops for higher nutritive values. At the present time this item receives very scant attention, but with the development of different social attitudes it could become of much greater importance.

The use of isotopes for fundamental research in nutrition and photosynthesis may lead to advances in genetics and other sciences that would have applicability to vegetable breeding. Whatever the developments in fundamental sciences, it is probable that several of them will have some applicability to vegetable breeding. As the fundamental sciences develop we can expect to have a continuous fund of new information for application to our problems.

It also appears that we need a more intensive program of cooperation between the other sciences and vegetable breeding. In many cases vegetable breeders and the workers in other fields of science, working at the same institution, are not aware of each other's problems. There may be many exceptions, but in most cases I believe that the scientists in theoretical fields are quite willing to give some help with the application of their theoretical findings to the applied sciences. I would like to urge vegetable breeders to use the help of the scientists in theoretical fields whenever possible. It has already been pointed out by Tukey (6) that cooperation is of benefit to both the applied and theoretical groups.

There is no sharp line of cleavage between theoretical and applied science. By careful use of his time it is possible in some cases for a worker to carry out both theoretical and applied research as a part of

the same program. In some cases material of great theoretical value may be equally important in the program of developing new varieties. By working continuously on some theoretical problems in addition to his applied problems the vegetable breeder has an avenue leading to wider contacts with workers in the theoretical sciences from which to draw new developments for application to vegetable breeding. If the breeder fails to take any of the theoretical problems which arise, he may find his interests in other fields waning, so that in the long run he cuts off his source of contact with other disciplines and isolates himself.

I have indicated above that vegetable breeding needs the development of the fundamental sciences so that we will continuously have new information to apply to the solution of breeding problems. I think one might logically inquire why there is so much fundamental work of possible importance to vegetable breeding that remains unapplied. I refer to such things as hybrid embryos reared on artificial media, as in the case of barley x rye hybrids, Brink *et al* (1). We have many cases in vegetable breeding where such wide crosses would be desirable. Possibly the tremendous backlog of problems on which the plant breeder knows he can make progress and lack of funds for undertaking long-term problems have discouraged attempts to make interspecific crosses.

Another field that has been somewhat neglected by the American vegetable breeder has been polyploidy. Certainly many vegetables would seem to provide desirable material if we use Levan's criterion (3) that improvements seem easiest gained in allogamous plants with low basic chromosome numbers which are grown for vegetative yield. There is some work in progress with polyploid onions, tomatoes and other crops. Dr. Karl Sax is working with a polyploid broccoli. In a letter (5) he states that he has been working with tetraploid broccoli for the past four years. I quote from his letter as follows: "The object was to produce a more uniform crop on the assumption that autopolyploidy would suppress genetic segregation. We also hoped that by crossing different tetraploid lines, we could obtain F_2 segregates which would have more than two sterile alleles. These would be expected to be self-fertile, if the sterile alleles in tetraploid broccoli behave as they do in tetraploid clover. We obtained several plants of tetraploid broccoli which were intercrossed to provide seed for the F_2. We grew about 100 F_2 plants this summer with rather surprising results. The tetraploids were at least as viable as the diploid controls, and in general were somewhat earlier in maturity. We made no actual yield tests since we were interested in obtaining seeds and testing for self-fertility. In general, the quality of the tetraploids was better than that of the diploids. Some of the segregates were self-fertile. We have made selections of some of the earlier and larger segregates which are self-fertile, and hope to produce a new tetraploid strain."

In Denmark, Larsen (2), working with an amphidiploid hybrid between *Solanum nigrum* and *S. nitridibaccatum*, found the production of berries in no case lower than in the parent form.

On this joint program Dr. Emsweller will doubtless refer to poly-

ploidy as a useful tool in the field of ornamentals, and Dr. Alderman may refer to some of the numerous examples of polyploidy in fruit breeding. With so much that has been done in other fields and with interesting beginnings in vegetable breeding it seems only fair to state that polyploidy is worth investigating in breeding programs involving certain types of vegetable crops.

With the tendency for greater specialization in areas of production there has been a distinct trend toward the production of varieties suitable only for certain places. In itself there is nothing alarming about this, but specialization in seed production is usually in some place far removed from the areas for market production or processing of a given crop. To be successful in this relationship, there must be a minimum of incompatabilities; that is, the variety that will produce in the shipping or processing areas, must also produce in the seed-growing areas. As the areas of production grow older and various difficulties arise, partial incompatabilities may also develop. This condition is true for several crops, but in order to make my meaning clear I would like to illustrate it with examples of snap bean production problems.

Due to dry growing seasons and very productive, irrigated farms, the West has attracted most of the snap bean seed-growing from other places in the country. At first these western areas produced very high yields from relatively low planting rates, and the seed so produced could, in most cases, be truthfully advertised as free from seed-borne diseases. Nearly every variety sent there for seed production has thrived and although some varieties have been much more productive than others, all common varieties have been successfully grown in the West. When U. S. No. 5 Refugee was produced by Wade and Zaumeyer (7) it was generally assumed, on the basis of evidence then available, that resistance to common bean mosaic was not needed in such early varieties of beans as Tendergreen and Stringless Black Valentine, since these possessed considerable tolerance. It was not long, however, until the proportion of cull beans due to common bean mosaic became a major source of loss to many growers in the South and elsewhere, indicating that their degree of tolerance is not enough. For resistance to common bean mosaic, several varieties have been developed some of which do well in the West while others may not prove to be satisfactory seed producers. The western growers have only recently been finding their yields of so-called mosaic-tolerant varieties reduced by common bean mosaic. Now that the disease is producing serious losses in both sections there is a common incentive to produce resistant varieties adapted to both sections.

Of much greater concern to the market bean sections of the South has been the occurence of curly top in the western seed-growing areas. Curly top has greatly and irregularly reduced seed yields and raised the price to the seed-consuming areas. What is needed are a few shipping varieties resistant to both curly top and common bean mosaic.

In a few places in the South root rots are causing some difficulties but apparently the West is having severe infestations. One indication of this is the planting rate in the Western seed-growing areas which in some cases has jumped from 20 to 30 pounds per acre of 20 years

ago to 90 to 120 pounds today, with a few fields being seeded at rates in excess of 200 pounds per acre. Heavier seeding reduces somewhat the relative damage from curly top, but the stands seem to indicate that heavier seeding is primarily to offset root rot damage.

In many of the bean-producing areas which depend upon rainfall for moisture, bacterial blights frequently cause serious damage. In some of the irrigated sections that would normally grow seed beans there is little or no seed production since these areas have sufficient blight so that the seed is unacceptable to areas subject to bacterial blights. The development of bacterial blight tolerant varieties such as Fullgreen promises to reopen these seed-producing areas.

From the viewpoint of the southern bean shipper, and of some processors perhaps, one of the most serious diseases is Sclerotinia. This disease is serious over all of southern Florida and in northern Oregon, and is coming to be of importance in Colorado. Sclerotinia is of minor importance in Idaho but of increasing importance in Wyoming. This information has been supplied by Dr. W. D. Moore (4) who is working on Sclerotinia diseases of vegetables in Florida. Dr. Moore has isolated Sclerotinia from western-grown seed. The fact that even a small amount can be carried on bean seed makes the problem of seed-borne infection of fields very serious.

Under the present conditions for one to produce a new bean variety for the South or for the West is not enough. To be economically justifiable it should be suited for both areas. This suitability should involve, in addition to satisfactory horticultural characteristics, resistance to common bean mosaic, bacterial blights, curly top, root rots, and Sclerotinia. Probably other diseases may have to be added to this list later. To be most effective the breeding work to produce such varieties should be cooperative between the regions involved. This cooperation will probably include mostly workers from the various State agricultural experiment stations and the United States Department of Agriculture, but certainly close working relationships with the various seedsmen should be obtained in all cases.

In illustrating the necessity of interregional cooperation by citing the work on snap beans I have not lost sight of other vegetables. In many cases regions are sufficiently large so that sub-areas within the regions have some very diverse problems. Most of the cooperative work in vegetable breeding undertaken in this country has arisen from the complimentary nature of the work involved and the insistence of the workers that they consider common problems together. In the next few paragraphs I shall mention briefly some of the more important cooperative vegetable breeding projects. These have all arisen as responses to various needs. It is quite probable that within the next several years there will be cooperative projects for other vegetables. Some workers have commented that they believe too much effort is devoted to some crops and not enough to others. This suggestion has considerable merit and I hope that a real balance of effort for the various crops can be attained.

The cooperative work on lima beans involving several State agricultural experiment stations and the United States Department of

Agriculture, is a good example of interregional cooperation involving areas for market production, processing, and seed-production.

In the last two years the STEP (Southern Tomato Exchange Program) plan of extensive exchange of materials between the various plant breeders has gotten off to an excellent start with trials of advanced breeding materials in most of the Southern States, in Hawaii, and Puerto Rico, and in several other tomato-producing States not in the South. The vegetable breeders involved in this work have been giving major attention to disease resistance, especially multiple disease resistance; but other items of horticultural importance, such as size, shape, color, cracking, fruit setting and others, are being considered.

Cabbage is another crop requiring interregional cooperation especially between the seed-growing areas and commercial crop-producing areas. In addition to the breeding work carried on by seedsmen there is cooperative work of the United States Department of Agriculture with the Wisconsin and the Washington Agricultural Experiment Stations for disease resistance and horticultural type. The Regional Vegetable Breeding Laboratory also has a program of breeding high-yielding, cold-tolerant strains of cabbage varieties suitable for southern conditions.

Under the National Potato-Breeding Program the United States Department of Agriculture and more than 30 of the State Agricultural Experiment Stations are cooperating in breeding Irish potatoes for adaptation, disease resistance, and other characteristics. This is probably the most extensive cooperative work in the country with a vegetable crop.

The onion breeding work has involved much cooperation between regions, with emphasis on disease and insect resistance and regional adaptability. This involves cooperation of several State Agricultural Experiment Stations and some seedsmen with the United States Department of Agriculture.

Another very vigorous project is the sweetpotato breeding work, with cooperation between most of the southern agricultural experiment stations and the United States Department of Agriculture. The problems involved have been mainly those of yield and of horticultural types as well as adaptation to various sub-regions of the area involved.

A striking instance of interregional cooperation is that of the Florida and Cornell Agricultural Experiment Stations in breeding celery for disease resistance and horticultural type. In Florida the celery will not produce seed and in New York Cercospora disease is not such a serious problem as it is in Florida.

Time does not permit more extensive illustration of cooperation, but I believe that sufficient examples have been cited to indicate not only the trends but also the various types of problems involved. I believe these are fairly typical of the specific breeding problems now being faced by vegetable breeders in the United States.

In addition to the specific problems we have certain general problems that are becoming more urgent as vegetable breeding becomes more productive of new strains and varieties. In very few cases are the workers satisfied with methods of releasing new varieties. For

extensive pre-release trials of new strains and varieties a considerable quantity of seed may be needed which the breeder may not be in a position to produce. With the trial grounds of seedsmen already crowded with trials and small increase lots it is not always easy to get them interested in undertaking seed increases for vegetable breeders at State and Federal institutions. I believe there may be need for setting up some agency in the seed-growing areas for the specific purpose of increasing seeds for Federal and State agencies although in many cases increases by seedsmen have been very satisfactory.

After the problem of sufficient seed for pre-release trials has been solved we still have the problem of the trials, their size, comprehensiveness, and interpretation. Most trials for which the vegetable breeder is able to arrange are usually on a small scale with only a very limited amount of replication or in some cases no replication. For adequate trials, before release or suppression can be decided upon, we need some trials of commercial size with opinions of a wide range of interested people, such as growers, buyers, shippers, consumers, and scientists. In many cases increase in yield is of less importance than improvement in quality, size, or market appeal; but unfortunately many tests are evaluated primarily on the basis of yield. The variety tests sponsored by the Southern Section of the American Society for Horticultural Science and carried out by State Agricultural Experiment Stations and the United States Department of Agriculture for many kinds of vegeables, are a step in the right direction. They need to be more extensive (that is, to have more participants) and more inclusive, and they need more support to be fully effective. I would like to see this type of cooperative set-up extended to other sections of the United States.

While tradition has some place in the development and selection of vegetable types for production, we should never forget that vegetable breeding is really only controlled evolution. When seedsmen and others, for instance, insist that a new snap bean variety to replace an older one should have some such superficial characteristic as a given seed color, in a case where color of seed coat does not matter in the product, then vegetable breeding is being made needlessly costly. We need sufficiently comprehensive tests of possible new varieties so that they can be strongly recommended to the public on the basis of their actual performance and characteristics. If this could be done there would be less effort on the part of salesmen and advertisers to stress the conventional rather than the new in new varieties. My long acquaintance with farm problems leads me to believe that farmers are much more concerned with marketability and productivity than they are with superficial characteristics. Perhaps some psychological studies would show whether I am correct or not in this observation. If I am correct, I believe much could be saved by advertisers seeking to introduce new vegetable varieties.

Last, but not least, in the process of releasing a new variety is the question of the companies or organizations to which the seed shall be released, and the timing of publicity. Shall all wholesale growers of seed of the particular crop under consideration be furnished seed, or

only those known to be actively interested? Shall distribution of seed be equal to all companies or roughly on the basis of their sales volume? Shall publicity on the new variety be withheld until seedsmen have sufficient seed for some distribution? In many cases these questions are answered differently by the various institutions doing vegetable breeding work; but among them all certain trends are developing as the breeders acquire more experience with varietal releases.

With the large amount of breeding work now being done and the many promising varieties that actually are never adequately tried out, it seems desirable to devote considerable effort to strain and variety evaluation. The introduction of new varieties is costly. In many cases seedsmen have strains or varieties of their own that they know are significantly better than varieties in production. Getting new varieties in sufficient quantity for distribution requires time and venture capital for seed production as well as considerable advertising, so that unless a strain is really outstanding — not just somewhat better — it may be discarded as not worth the risk and effort involved. Complaining about the excessive number of varieties appears to me to be a waste of time. A concerted effort by plant breeders, seedsmen, food processors, and vegetable producers to provide really adequate tests of all the advanced breeding material available would do more than anything else to solve the problem of too numerous vegetable varieties. If plant breeding work is worth doing, surely the results are worth evaluating. The American farmer is an impatient man, and rightly so, I think. If those interested in new varieties would cooperate to obtain varietal evaluations quickly our farmers would not have to wait nearly so long for the new varieties, which in some cases mean the difference between growing or not growing a particular crop.

Whenever a new variety is introduced usually several years must elapse before decisions can be made as to the area or region to which it is adapted. With full cooperation between those mentioned above it would seem possible to provide a fairly good indication of regional adaptation before release if really comprehensive trials could be set up in numerous locations.

Summary

Important specific problems confronting vegetable breeders include these:

1. More adequate fundamental research so that breeders will have a continuous fund of new knowledge for application to their problems.
2. A more intensive program of cooperation between workers in the basic sciences and in vegetable breeding.
3. The problem of making use in vegetable breeding of fundamental information already available but now largely ignored.
4. Importance of interregional cooperation, as illustrated by special problems in the breeding of a number of vegetable crops.
5. The general problem of release of new varieties, has become intensified, and suggestions are made for comprehensive tests of breeding material and techniques of release.

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Some Effects of Blossom Removal on Vegetative Development and Defoliation in Determinate Tomato Plants[1]

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During the last ten years a large number of tomato varieties have been grown in trials at this station. Plants of the early determinate varieties (6) such as Victor, Bounty, Pennheart, Chatham, Bison and Red River invariably become almost completely defoliated about the time the first fruit ripens or slightly later. These determinate plants frequently produce blossom clusters between alternate leaves as compared to indeterminate plants which produce their blossom clusters between every set of three leaves. Generally the stems of determinate varieties grow a short distance and then a blossom cluster appears at the tips, terminating their growth and making a very compact plant (6). Defoliation proceeds very rapidly in the varieties mentioned above and does not extend over a fairly long period as is usual with such standard varieties as Bonny Best, Marglobe and John Baer.

Fruits on the defoliated plants are more subject to sun scald, cracking, flabbiness, poor coloration and off-flavors. Naturally, such fruit cannot be marketed along with the best grade of produce.

Horsfall and Heuberger (1) have made a rather thorough study into the causes for defoliation on tomatoes and have concluded that the following factors are responsible: fungi and insects, weather, and abnormal physiology which includes effects of shading, age of tissue, fruit load, and nutrition. They stated that *Alternaria solani* was responsible for 90 per cent of the defoliation encountered during their experiments. These men were careful, however, to point out the interrelation of the factors responsible for defoliation. One significant point was the fact that "bull" plants, that is, those that set no fruit, seldom are afflicted seriously with defoliation. "Similarly, the disease seldom or never attacks a crop in the field until the plants begin to set fruit."

For years experiments have been conducted that displayed the effects of fungicides in reducing defoliation, but since the application of these compounds did not appreciably correct the difficulty with these varieties, some studies were made to determine the relation of fruit load to defoliation and how defoliation might be retarded or reduced.

As early as 1899 Mattriolo (2) noted the great amount of vegetative growth of all organs in plants of Vicia faba that had their flowers removed. The classical studies of Murneek (3, 4) have also shown this relationship to hold with Bonny Best tomatoes. He sums up the effect in the following statement: "In every case a maximum crop of fruits had a strikingly retarding effect on vegetative growth and development". Using the variety Scarlet Dawn, Horsfall and Heuberger (1) found that defruiting caused an increased amount of foliage and their

[1]Contribution No. 644 of the Massachusetts Agricultural Experiment Station.

data indicate a fairly general relation between fruit load and magnitude of infection.

Materials and Methods

The variety Pennheart (5) was selected for use in these studies since it was one of the worst in losing its leaves early. The seed was sown early in April and the plants were given good culture until set in the field late in May. The land was fertilized uniformly with a 5–8–7

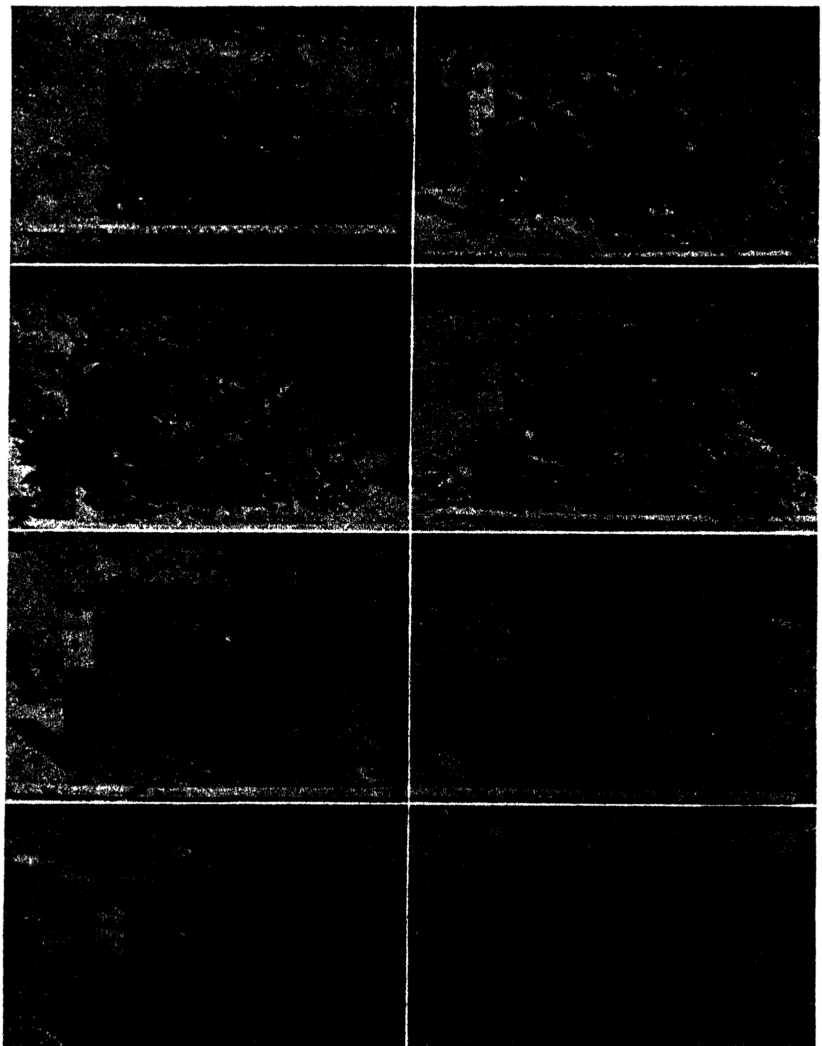

Fig. 1. Showing effects of fruit load on vegetative development of the plants. Photographed August 4, 1947.

fertilizer at the rate of 1,500 pounds per acre. The soil was cultivated shallowly, often enough to discourage weed growth. No insecticides or fungicides were applied during the course of the experiments.

The studies described here were conducted in 1945, 1946, and 1947. The treatments consisted solely of defloration or blossom removal from plants excepting the check where no blossoms were removed. The blossoms were removed simply by clipping them loose from the plants with the thumbnail prior to anthesis of the oldest blossom in each cluster.

The treatments given included the following:

1. Check, that is no blossoms removed from any clusters.
2. All blossoms removed (no fruit developed on these plants).
3. All blossoms removed except the first cluster.
4. All blossoms removed except the first two clusters.
5. All blossoms removed except the first three clusters.
6. All blossoms except the proximal one removed from each cluster.
7. All blossoms except the proximal two removed from each cluster.
8. All blossoms except the proximal three removed from each cluster.

Three plants were included in each treatment and the treatments were replicated three times making nine plants in all under each treatment.

RESULTS

Fig. 1 illustrates rather clearly the relative effects of the fruit load on the vegetative development of the plants. This association held fairly constant for all treatments during the three years of the experiments. These photographs were made on August 4, 1947, as the first fruits were ripening and defoliation of the check plants had just begun. The plants shown here are in no way an exaggeration of the response to the treatments.

The data in Table I also demonstrate the profound influence of fruit load on vegetative growth. Data from 1945 and 1946 are not included, but are consistent with the results reported here.

TABLE I—PLANT DEVELOPMENT AND FRUIT YIELD AS INFLUENCED BY VARIOUS DEFLORATION TREATMENTS IN THE VARIETY PENNHEART

Treatment	Data of August 4, 1947 (Just as the First Fruits Were Ripening)				Data for the Season's Total (1947)		
	Average Plant Spread (Inches)	Average Plant Height (Inches)	Weight of Fruit Per Plant (Pounds)	Weight of Plant Without Fruit (Pounds)	Number Fruits	Total Fruit Weight (Pounds)	Average Fruit Weight (Pounds)
1. Check	22	16	6.35	2.00	56	14.4	0.26
2. No fruit	36	28	0.00	5.70	0	—	—
3. One cluster	36	27	1.70	3.00	15	5.8	0.39
4. Two clusters	24	16	3.65	1.62	28	10.6	0.38
5. Three clusters	24	14	5.20	2.00	29	11.8	0.41
6. One fruit per cluster	36	20	4.75	2.55	76	29.4	0.39
7. Two fruits per cluster	24	14	5.55	2.35	83	28.1	0.34
8. Three fruits per cluster	24	14	4.85	2.00	78	30.3	0.39

Plant response, in general, was very similar to that reported by other investigators who worked with indeterminate tomato plants. Growth of the plants in treatment 2 (no fruit) was very vigorous and the leaves on these plants were larger and thicker and the total green weight greater than in any other treatment. The growth habit of the treated plants was changed somewhat since blossom removal delayed the appearance of the terminal blossom cluster. This delay was correlated with the number of blossoms removed. The growth in treatment 2 where no fruit was allowed to develop was not unlike that found in indeterminate varieties.

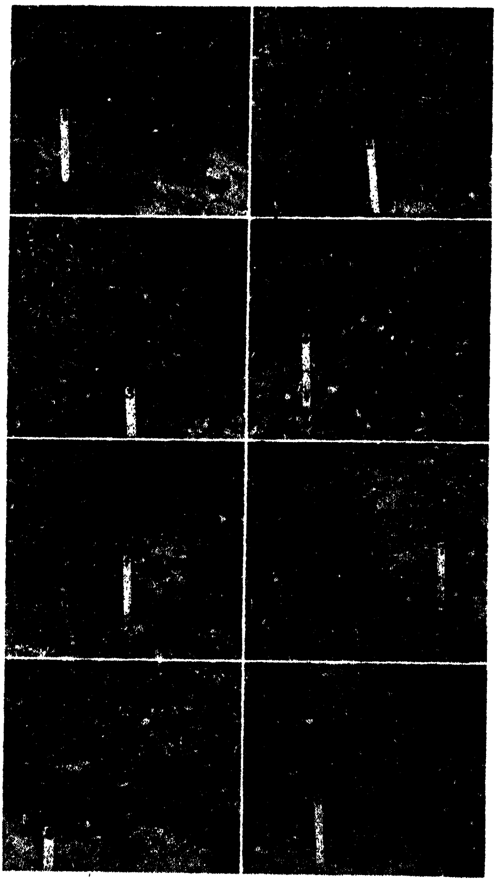

FIG. 2. Showing extent of defoliation by September 4.

Fig. 2 shows the plants in a later stage of development. These were made on September 4 when defoliation was practically complete on the check plants. Plants in treatment 8 were also very largely defoliated by this time. On the other hand, the plants in treatment 2, where all blossoms were removed, had not lost any appreciable amount of foliage. The treatments between these extremes of blossom removal were defoliated approximately in inverse proportion to the fruit load. This was especially apparent among treatments 6, 7, and 8. As might be expected, the fruit size was more uniform in treatment 6 than in any other treatment.

One of the most noteworthy effects was that the total yields of fruit from treatments 6, 7 and 8 were significantly greater than from any of the other treatments, including the check, during the three years of the experiment. This indicates that plant breeders may benefit from selecting types that bear fewer blossoms per cluster when working with tomatoes having a determinate habit of growth. This may also increase the fruit size since the average size of fruit from the check plots was consistently smaller than those from other treatments.

SUMMARY

Early determinate varieties of tomatoes are very susceptible to an acute type of defoliation. Plants bearing a heavy load of fruit are most susceptible to defoliation. Conversely those without fruit are least subject to this malady. No practical solution to this problem is suggested except that plant breeders may be able to select types that set fewer fruits on each cluster of blossoms.

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The Effect of Minor Elements and Widely Varying Fertility Levels on the Yields of Nine Vegetable Crops[1]

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The increased incidence of nutrient disturbances in vegetable crops on the coastal plain soils of Delaware has indicated the need for a study of minor elements. This might have been expected since a recent study (unpublished) of Delaware soils revealed that they have, in general, a low exchange capacity and are low in nitrogen, available phosphorus, and potassium, and possibly certain minor elements. In some crops such as tomatoes, squash, cucumber, muskmelon, and watermelon, these disturbances develop to such an extent that serious economical losses are prevalent. In other crops, such as sweet corn, pepper, and potato losses also occur but they are of minor magnitude.

Premature defoliation of tomato plants frequently occurs, beginning with the yellowing of the leaves soon after the first fruit has set. As the season progresses, the yellow leaves drop off and the plants succumb several weeks before the end of the growing season. With squash, there exists a disturbance which causes rapid dying of the plants before the fruit reaches maturity. A similar condition exists in cucumber, muskmelon, and watermelon. Other abnormalities which resemble the symptoms of boron deficiency have appeared in celery, cabbage, turnip, and cauliflower. Still other deficiency symptoms which appear to be due to the lack of one or more of the major elements and the lack of magnesium have been observed.

Plant pathologists and entomologists have found no evidence that these abnormalities are caused by diseases or insects. This indicates that these disorders originate in the soil. Hence it seemed imperative to determine the actual factors which induce these disturbances in order to devise practical means of correction. An exploratory experiment was, therefore, designed to reveal information which might be of value in further investigations.

Plots for this study were established at the Substation near Georgetown, Delaware, in the spring of 1947. The soil, which is representative of large areas in Kent and Sussex Counties, is a loamy sand of medium fertility and low organic carbon content. According to quick tests, before fertilizer applications, it contained a fair supply of nitrate nitrogen, calcium, and magnesium; a poor supply of phosphorus and organic carbon; and a good supply of potassium. The pH of this soil was 6.2. Each treatment was replicated three times. The vegetables studied together with the varieties and plot sizes were:

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Vegetable	*Variety*	*Plot Size (Feet)*
Tomato	Rutgers	40 x 145.0
Potato	Irish Cobbler	40 x 35.0
Sweet Corn	Goldengrain	40 x 10.5
Broccoli	Italian Green Sprouting	40 x 3.5
Cabbage	Penn State Ballhead	40 x 10.5
Sweet Potato	Maryland Golden	40 x 21.0
Watermelon	Coker	40 x 30.0
Muskmelon	Jumbo Hale's Best	40 x 36.0
Squash	Boston Marrow	40 x 16.0

All fertilizers, including the minor elements which were mixed with the commercial fertilizer, were broadcast on the soil surface with a grain drill and plowed down in mid-April. All cultural operations with each vegetable crop were uniform. The treatments consisted of three levels of fertility (0, 1500, and 3000 pounds of a 4–8–12 fertilizer per acre), three minor elements (boron, copper, and magnesium), and Es-Min-El, which is a substance containing a combination of minor elements. All of the minor elements were applied in conjunction with 1500 pounds of a 4–8–12 fertilizer per acre. The yield data from all treatments are presented in Table I. Analysis of variance was used in analyzing the data.

TABLE I—EFFECTS OF MINOR ELEMENTS AND FERTILITY LEVELS ON THE MARKETABLE YIELD OF NINE VEGETABLE CROPS

Treatment Per Acre	Tomatoes (Tons Per Acre)	Potatoes (Bu Per Acre)	Sweet Corn (Tons Per Acre)	Broccoli (Lbs Per Acre)	Cabbage (Tons Per Acre)	Sweet Potatoes (Bu Per Acre)	Watermelons (Tons Per Acre)	Muskmelons (Tons Per Acre)	Squash (Tons Per Acre)
No fertilizer	9.67	151	3.11	1,213	2.33	140	8.91	6.55	3.32
1,500 lbs 4-8-12	14.33	190	4.15	2,054	4.36	257	11.11	9.32	4.93
3,000 lbs 4-8-12	14.10	199	5.19	2,582	5.86	257	11.24	12.39	7.24
1,500 lbs 4-8-12 +20 lbs borax	17.63	249	4.77	2,178	6.64	238	11.60	11.17	5.99
1,500 lbs 4-8-12 +50 lbs $MgSO_4$	14.63	199	4.72	1,805	6.27	263	10.60	9.94	6.72
1,500 lbs 4-8-12 +50 lbs $CuSO_4$	15.97	226	4.98	2,240	6.85	230	11.92	10.10	7.62
1,500 lbs 4-8-12 +50 lbs Es-Min-El	17.00	229	4.67	2,645	6.53	251	12.87	10.33	6.78
Difference required for significance with odds of 19:1	1.90	31	0.84	1,213	1.60	31	2.43	2.01	0.81
Difference required for significance with odds of 99:1	2.66	44	1.14	1,711	2.25	44	3.41	2.83	1.13

As would be expected, practically all of the crops gave significant yield increases when 1500 pounds of a 4–8–12 fertilizer per acre was used in contrast to no fertilizer. The notable exception to this was broccoli, which came into production, during a drought, late in the season. A comparison of the yields from the plots receiving 1500 pounds and those receiving 3000 pounds reveal that only sweet corn, muskmelon and squash gave a significant yield increase from the additional 1500 pounds of fertilizer.

With the nine vegetable crops tested, several responded to one or more of the minor elements. Tomato, potato, cabbage, and squash pro-

duced significantly greater yields when 20 pounds of borax was applied per acre. Only cabbage and squash responded to magnesium while potato, cabbage, and squash responded to copper. When the combination of minor elements was used, tomato, potato, cabbage, and squash yields were increased significantly. One of the most phenomenal yield increases, due to a minor element, was that of tomato. Boron increased the yield by 3.3 tons per acre. This yield increase was highly significant. Other yield increases due to minor elements which also were highly significant are: tomato with Es-Min-El; cabbage with copper and with boron; and squash with Es-Min-El, with magnesium, and with copper. None of the minor elements, at the rates used, resulted in a significant yield reduction.

Since the work herein reported was conducted in a single season on only one soil type, the results, although significant, should not be considered conclusive. These results, however, may have value in determining the vegetable crops that are apt to respond to minor elements and high fertility levels on coastal plain soils.

Tomato Color As Influenced by Variety and Environment[1]

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THE American public is becoming increasingly color conscious of the fruits and vegetables it consumes. Because highly colored foods are attractive and are in some cases associated with high nutritive values, color has assumed great importance in consumer appeal. The enterprisers engaged in the production, processing and merchandizing of tomatoes and tomato products are finding that color is very important. In the tomato canning industry, for example, color is considered one of the determining influences on the prices received for tomato products. A premium is usually paid for canned tomatoes which are superior in color.

The object of this investigation, conducted in 1946, was to study the factors responsible for color in tomatoes and to determine the effects of different varietal and environmental conditions on color development. With a view toward improved tomato color, the response of fruits to environmental treatments should be of interest and value to all concerned.

REVIEW OF LITERATURE

Lycopene, a red carotenoid pigment, is largely responsible for color in red tomatoes. Carotene, a yellow pigment and a precursor of vitamin A, is the principal coloring agent of yellow tomatoes and is also present in large quantities in red tomatoes.

In color comparison of red tomato varieties, MacGillivray (5) found little practical significance of color differences due to variety. Lindstrom (3) and LeRosen, Went and Zechmeister (2) found that red tomatoes with a colorless skin were pink or purple in color, whereas, those with a yellow skin were a brilliant red or orange-red in color.

Smith (11) and Duggar (1) showed that light has no effect on lycopene production except indirectly by increasing the temperature, but light does have considerable effect on the production of carotene. Red tomato fruits exposed to a high light intensity showed a greater development of carotene than fruits receiving a lesser amount. According to MacGillivray (4), the sides of tomato fruits exposed to continuous light during the day had a higher temperature and were more yellow in color than the shaded sides, indicating that more carotene was present and that lycopene production may have been suppressed.

Duggar (1) showed that temperature is an important factor in lycopene development. He found that fruits picked when green and ripened off the vine showed the optimum ripening temperature to be 18 to 23 degrees C for maximum lycopene development. He also found that above 30 degrees C, practically no red coloring appeared in the tomatoes, but the tomatoes did lose their green color and became yellow. When fruits were ripened at temperatures above 30 degrees

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C, then placed at temperatures near the optimum, red coloring appeared, indicating that the suppression of lycopene at high temperatures did not destroy its capacity for development. Similar experiments were conducted by Went, LeRosen and Zechmeister (14) and Vogele (13) who made the color measurements on a quantitative basis and got essentially the same results.

In a chromatogram of pigments of the Tangerine tomato, Zechmeister, LeRosen, Went and Pauling (15) discovered prolycopene, a carotenoid which is a stereoisomer of lycopene. The Tangerine tomato is brilliant orange in color and its main pigment is prolycopene. Porter and Zscheile (9) isolated relatively large quantities of prolycopene from the Golden Jubilee variety which is a selected progeny of Tangerine and a red variety.

Materials and Method of Procedure

Six varieties of red tomatoes were used for color measurement comparisons. The varieties used were Pritchard, Marglobe, U. S. No. 24, Pan America, Rutgers, and Indiana Baltimore. They were grown in randomized blocks with three replications. The effects of shading and exposure to sunlight on color were determined for each variety. Jubilee was used as the yellow variety for a color comparison of shaded and unshaded fruits and to determine the effects of temperature on the ripening of detached yellow fruits. Rutgers tomatoes were used in determining the effects of temperature on the ripening of detached fruits of a red variety. All tomatoes were grown on a fertile, well-drained Clarion loam soil which had received an application of barnyard manure and superphosphate.

Four incubators were used in ripening the Rutgers and Jubilee fruits and were maintained at the following temperatures: 15, 20, 25, and 30 degrees C. The incubator temperatures were standardized before the fruits were placed in them and daily temperature records were taken. The maximum daily fluctuation of temperature was approximately 1 degree C. The fruits were placed in baskets in two replications for each of the two varieties ripened. To maintain a high and constant humidity, a large dish of water for evaporation was located in each incubator.

A disc colorimeter similar to the type described by Nickerson (7) was constructed for the measurement of color in tomatoes. Maxwell discs, purchased from the Munsell Color Company, were used on the disc colorimeter for matching with the colors of tomatoes. The disc colorimeter is adapted for the measurement of color in various products. Nickerson (8) described its usefulness in measuring color in various grades of cotton and Sparks (12) used a multiple form of rotating discs in matching skin colors of potatoes.

The Munsell (6) method of color notation was used as the basis for expressing color in tomatoes. The Munsell notation is based on the three psychological attributes of color: hue, value and chroma. These three attributes may be spoken of as the three dimensions of color.

Munsell described hue as the quality by which we distinguish one color family from another, such as, red from yellow, or green from

blue or purple. Value was described by Munsell as the quality by which a light color is distinguished from a dark one. He described chroma as the strength or intensity of a color. All three attributes are essential for any color and use of the Munsell notation describes a color in all three terms. There are 10 major hues in the Munsell hue circuit which are arranged in spectral order as follows: red, yellow red, yellow, green yellow, green, blue green, blue, purple blue, purple and red purple. By taking a point midway between red and red purple and designating that point as 0 or 100, the major hues are given numbers with red as 5, yellow red as 15, yellow as 25, and so on with the corresponding breakdown of numbers and decimals between the major hues. On the value scale, one extreme is black and the other extreme is white and the various degrees of gray are located between and given numerical terms from 1 (black) through 9 (white). Chroma is depicted by increasing strength of color beginning numerically with 0.

The Maxwell discs used in color measurement had the following Munsell notations:

7R–3.2/9.4	(glossy red)
2.5YR–5.4/10.6	(glossy yellow red)
N–1.0/0	(neutral — black)
N–9.0/0	(neutral — white)
4.5Y–8.4/13.3	(yellow)
6.5GY–6.2/9.0	(green-yellow)

Readings of the per cent of each Maxwell disc needed to match the tomato fruits were converted to Munsell notations in the manner described by Nickerson (*7*).

Approximately 100 tomato fruits were measured for practice in acquiring the skill needed for colorimetric readings of large quantities of tomatoes. At the same time an effort was made to develop a standard maturity so that all fruits measured for color would be of the same degree of ripeness. Since color was the variable factor being measured, it could be used only generally in determining maturity of fruits. The relative firmness of the fruits and the ease with which they could be detached from the plants were measures of maturity which were used in determining ripeness. Skill and experience were of prime importance in judging uniformity of maturity. All fruits were measured for external color.

Results and Discussion

Hue, value and chroma readings of tomato fruits were taken on the disc colorimeter during August, September and October, 1946. In the various phases of the investigation, a total of 370 tomato fruits were measured for color.

The Influence of Variety:—Hue, value and chroma readings for the six red varieties measured are shown in Table I. The Rutgers variety was used as a standard of good color since it is very popular with the tomato canning industry because of its red color. The hue readings indicate that Marglobe and U. S. No. 24 were not significantly different from Rutgers, whereas, Pritchard, Pan America and Indiana Bal-

timore were highly significant. On the hue scale, Pritchard, Pan America and Indiana Baltimore were less red and more yellow in color than the other three varieties. In the value readings, Pritchard was the only variety which was significantly different from Rutgers. The position of Pritchard color on the value scale indicates that a lighter shade of gray was present than in the other varieties. Fruits of the Pritchard variety were also significantly different in chroma from the fruits of Rutgers. All other varieties showed no significant differences from Rutgers. This indicates that Pritchard with its yellower hue and lower value had more strength of color which intensified its tendency toward yellowness.

TABLE I—COLOR COMPARISONS OF SIX VARIETIES OF RED TOMATOES (MEAN OF 30 FRUITS)

Varieties	Variety Means		
	Hue	Value	Chroma
Pritchard	9.18	3.76	9.37
Marglobe	8.75	3.58	9.17
U. S. No. 24	8.84	3.59	9.15
Pan America	9.05	3.66	9.19
Rutgers	8.75	3.60	9.21
Indiana-Baltimore	8.97	3.66	9.21
Significance Levels:			
5 per cent level	0.15	0.13	0.12
1 per cent level	0.21	0.18	0.17

A possible explanation for the poorer color of the Pritchard fruits may be the open nature of the plants which caused greater exposure of fruits to sunlight. In mid-July of 1946, a windstorm at Ames, Iowa, caused lodging of many tomato vines, especially of the Pritchard variety. This exposed many of the fruits to intense sunlight and also increased the amount of light reaching the shaded fruits.

The yellow variety, Jubilee, was also measured for color, and the color readings indicated that Jubilee fruits are yellow-red or orange in hue, medium gray in value and high in chroma or color intensity. The bright orange color is due largely to the presence of prolycopene, the carotenoid discovered in the Tangerine tomato by Zechmeister, LeRosen, Went and Pauling (15), and isolated from the Jubilee tomato by Porter and Zscheile (9).

The Influence of Light:—A study of the effects of light on color during the ripening period was made within each of the tomato varieties as shown in Table II. Fruits exposed to full sunlight during the ripening period were compared colorimetrically to fruits ripened in the shade of plant foliage.

Differences between shaded and exposed fruits of the red varieties were highly significant for hue, value and chroma. Interpreted in descriptive color terms, this indicates that fruits ripened in the shade of foliage, at reduced light intensity are more red, closer to the black extreme of the value scale and slightly lower in chroma than the exposed fruits. The three color attributes of the shaded fruits combined to form a deep, solid and brilliant red color.

TABLE II—COLOR COMPARISONS OF SHADED AND EXPOSED FRUITS OF SIX VARIETIES OF RED TOMATOES (MEAN OF 15 FRUITS)

Varieties	Fruits Shaded			Fruits Exposed		
	Hue	Value	Chroma	Hue	Value	Chroma
Pritchard	8.83	3.64	9.34	9.53	3.88	9.39
Marglobe	8.34	3.46	9.16	9.16	3.69	9.17
U. S. No. 24	8.38	3.47	9.18	9.30	3.71	9.12
Pan America	8.66	3.54	9.16	9.43	3.78	9.21
Rutgers	8.29	3.45	9.18	9.21	3.75	9.24
Indiana Baltimore	8.46	3.48	9.16	9.47	3.83	9.25
Significance Levels:						
5 per cent level	0.24	0.08	0.04			
1 per cent level	0.35	0.11	0.06			

Smith (11) found that light in itself had no effect on lycopene development. At first glance, it appears that the data shown here conflicts with the results that Smith obtained. However, MacGillivray (4) reported that fruits and sides of fruit exposed to light were significantly higher in temperature than those which were shaded. Consequently, it appears that light exerts its influence on tomato color by increasing the temperature, which according to Duggar (1), Vogele (13), Rosa (10) and Went, LeRosen and Zechmeister (14) suppresses the development of lycopene.

Because of the high content of yellow color in the exposed fruits, the results show that an abundance of light apparently does not decrease carotene content. This is in accord with Smith's (11) findings that light was favorable for the maximum development of carotene.

No significant differences were found between shaded and exposed fruits of the Jubilee variety in either hue, value or chroma. This gives evidence that sufficient light is available for carotene development when fruits are shaded and that an excess of light is not harmful to carotene production. Prolycopene, present in the Jubilee tomato, is apparently affected by light in much the same manner as carotene.

The Influence of Temperature:—It was mentioned previously that light caused an increase in temperature of tomato fruits and that temperature was an influencing factor in the development of lycopene. The detached green tomato fruits in this phase of the experiment were ripened in darkness in the incubators with temperatures as the only variable environmental factor. After 3 weeks of ripening at the various storage temperatures, the Rutgers and Jubilee fruits were removed and measured for color on the disc colorimeter.

The hue, value and chroma readings of Rutgers tomatoes ripened at various temperatures are shown in Table III.

Highly siginficant results for hue were obtained for the effects of temperature. The temperature which produced the reddest hue was 20 degrees C, and the fruits ripened at 15 and 30 degrees C differed in a highly significant manner from those ripened at 20 degrees C. At 15 degrees C the fruits were pinkish in color, whereas at 30 degrees C they were approximately midway between yellow-red and yellow on the hue scale. Although both these temperatures ripened fruits which differed at the highly significant point from 20 degrees C, those rip-

TABLE III—Color Comparisons of Rutgers Tomatoes Ripened in Storage at Four Different Temperatures (Mean of 20 Fruits)

Temperature (Degrees C)	Hue	Value	Chroma
15	8.19	3.88	8.38
20	7.51	3.73	8.29
25	7.75	3.68	8.58
30	19.05	6.69	8.49
Significance Levels:			
5 per cent level.......	0.75	0.11	No sig. diff.
1 per cent level.......	1.37	0.21	

ened at 15 degrees C are more desirable from the standpoint of red color than those ripened at 30 degrees C.

In the value measurements, temperature was also highly significant and the darkest value was found at 25 degrees C. The value of fruits ripened at 15 degrees C gave significant differences and those at 30 degrees C, highly significant differences when compared to fruits kept at 25 degrees C. The darker values are more desirable from the standpoint of color in tomatoes for they add more depth of color, therefore, fruits ripened at 20 and 25 degrees C showed the best value readings. The pinkish cast of the fruits ripened at 15 degrees C is due to the presence of more of the neutral white which blends with the red hue. At 30 degrees C the yellow color contains even more of the neutral white and the fruits take on the appearance of a yellow variety.

No significant differences were found from the chroma readings for Rutgers fruits ripened in storage. Although wide variations were observed in hue and value at different temperatures, the intensities of the resulting colors are very near the same point on the chroma scale.

Of the four temperatures used in this investigation, the optimum temperature for ripening Rutgers tomatoes for best color falls into the range of 20 to 25 degrees C. This range could very likely be narrowed down by ripening green fruits at closer spaced intervals of temperature. Duggar (1) suggested an optimum of 18 to 23 degrees C for red tomatoes and Vogele (13) found the optimum temperature to be 24 degrees C.

The phase of the experiment in which Jubilee fruits were ripened at the four storage temperatures was conducted in the same manner as for the Rutgers fruits ripened in storage.

The color attribute readings for Jubilee fruits are shown in Table IV.

As in Rutgers, the fruits ripened at 20 and 25 degrees C had the

TABLE IV—Color Comparisons of Jubilee Tomatoes Ripened in Storage at Four Different Temperatures (Mean of 20 Fruits)

Temperature (Degrees C)	Hue	Value	Chroma
15	19.03	6.74	10.41
20	17.79	6.41	10.54
25	17.93	6.50	10.22
30	18.95	6.69	9.72
Significance levels:			
5 per cent level.......	0.39	0.12	0.38
1 per cent level.......	0.72	0.21	0.70

most desirable hue, however, the extreme temperatures of 15 and 30 degrees C did not produce as widely varying results as in Rutgers. This indicates that carotene is not inhibited by extreme temperatures to nearly as great a degree as is lycopene. In fact, carotene may not be inhibited to any degree and the difference may be due to a suppression of prolycopene at high and low temperatures since prolycopene imparts a brilliant orange color, and the fruits ripened at 15 and 30 degrees C were lacking in the orange hue. The 20 and 25 degrees C temperatures for ripening fruit gave a darker value which adds depth of color. Fruits ripened at 15 and 25 degrees C showed no significant differences in chroma, however, the color intensity of the 30 degrees C fruits was significantly less than those ripened at the other three temperatures.

The optimum temperature for ripening Jubilee fruits appears to be 20 to 25 degrees C because of the desirable hue, value and chroma attributes at those two temperatures. Although fruits ripened at 15 degrees are high in chroma, the high value and hue impart a paler color to the fruit. The fruits stored at 30 degrees C were significantly poorer in hue, value and chroma which combine to make this the poorest ripening temperature of the four temperatures used. The effects of the various temperatures were not as widely variable in the Jubilee fruits as they were with Rutgers. In both varieties light was not essential for ripening fruits picked at the mature green stage.

Summary

Tomato fruits subjected to various treatments of environmental factors were measured for color on a quantitative basis. Color readings were made on a disc colorimeter and converted to Munsell notations of hue, value and chroma.

Varieties of red tomatoes showed color differences. Rutgers, Marglobe and U. S. No. 24 were outstanding with their brilliant red color and Pritchard had the poorest color in 1946.

The effects of light on red tomatoes as shown by measurements of shaded and exposed fruits were highly significant. Shading by plant foliage during the ripening period produced a deeper red color than the fruits exposed to full light.

Fruits of the Jubilee variety were not significantly affected in color by shading and full light.

The optimum temperature for ripening Rutgers and Jubilee tomatoes in storage was found to be 20 to 25 degrees C for maximum color development.

Light was not essential for color development when Rutgers and Jubilee fruits were picked at the mature green stage.

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The Effect of Plowing and of Discing Soils on the Yields of Tomatoes, Muskmelons, and Potatoes[1]

By E. P. BRASHER, *Delaware Agricultural Experiment Station, Newark, Del.*

IN recent years the topic of plowing versus discing of soils in preparation for the planting of crops has been popularized by the press, agriculturists, novel writers, and others. In all of this publicity, there seemed to be very little experimental evidence to justify the recommendation of plowing over discing or that of discing over plowing. An experiment was, therefore, designed to test the yielding ability of certain vegetable crops, when planted on plowed and on disced soils. This paper deals with the results obtained by the use of both methods.

Uniform plots for this study were established at the Substation near Georgetown, Delaware, in the fall of 1944. The soil was a loamy sand of low fertility and low organic carbon content. Each plot consisted of an area of 36 by 300 feet and was replicated four times. A rye cover was grown over the entire area during each winter. In each spring, when the rye was approximately 2 feet high, the respective areas were plowed or disced according to plan. The depth of plowing was approximately 7 inches while that of discing was about 4 inches. Rutgers tomatoes, Jumbo Hale's Best muskmelons, and Irish Cobbler potatoes were grown respectively during the seasons of 1945, 1946, and 1947. All operations in the production of these crops, with the exception of the plowing or the discing, were uniform.

Records were taken at harvest time of the weight of marketable tomatoes, number and weight of marketable muskmelons, and total weight of potatoes. The tomatoes were considered marketable when they would conform to the U. S. No. 1 or No. 2 grade. The muskmelons were classified as marketable if they were acceptable on local markets. Analysis of variance was used in analyzing the data.

A comparison of the mean yields is given in Table I and it shows that the yields of muskmelons and potatoes from the plowed areas are significantly greater than those from the disced areas. There was no significant difference in the yields of tomatoes from the two treatments, although a slight trend favored the plowed areas.

At the beginning of this experiment and each year thereafter, representative soil samples from the plowed and from the disced areas were taken and analyzed for available nitrogen, phosphorus, potassium, magnesium, and calcium. Organic carbon and pH determinations were also made. In all of these determinations, no significant change could be detected in soil content between the plowed and the disced areas. It is, therefore, very difficult to offer an explanation why such large yield differences between the plowed and the disced areas existed when muskmelons and potatoes were grown. Since the soil (loamy sand) on which these crops were grown became hard and very com-

[1]Published as Miscellaneous Paper No. 39 with the approval of the Director of the Delaware Agricultural Experiment Station. Contribution (No. 15) of the Department of Horticulture. November 19, 1947.

TABLE I—RESULTS OF TOMATO, MUSKMELON, AND POTATO YIELDS FROM PLOWED AND FROM DISCED SOILS

Treatment	Tomatoes (1945)	Muskmelons (1946)		Potatoes (1947)
	Marketable (Tons Per Acre)	Marketable (No. Per Acre)	Marketable (Tons Per Acre)	Total (Bu. Per Acre)
Plowed	9.75	3,243	3.96	289
Disced	9.53	2,311	2.77	239
Difference required for significance with odds 19:1	N.S.	985	0.49	20
Difference required for significance with odds 99:1	N.S.	1,492	0.74	29

pact at times during the growing seasons, it is possible that better aeration and moisture conditions existed on the plowed areas. This conceivably could be brought about by a better physical condition of the soil on the plowed areas. During the three years of this experiment, the disced areas were never plowed while the plowed areas were plowed twice a year, once before seeding the cover crop and again before seeding the cash crop. This may possibly explain why there existed such a small difference in tomato yields and such a large difference in the muskmelon and potato yields. At the beginning of this experiment, when tomatoes were grown, it is believed that the physical condition of all the plots were fairly equal but, as time progressed, the physical condition of the disced plots became less favorable for plant growth.

A Preliminary Study of the Effect of Axillary Foliage on Yield of Tomatoes[1]

By D. D. HEMPHILL and A. E. MURNEEK, *University of Missouri, Columbia, Mo.*

IN the tomato the growth of the axillary shoots follows a definite pattern. The shoots arising from axillary buds immediately below each flower cluster usually grow more rapidly than the shoots arising from the axillae of other leaves. Upon the observation of this pattern of growth, the question was posed as to what effect these rapidly growing shoots might have upon the set and the development of the fruit.

In growing tomatoes in the greenhouse and sometimes in the field also, it is a common practice to train the plants to a single stem by removing all side shoots, therefore, it was thought desirable to study the influence of some of the axillary foliage on fruit production. The method used in these experiments was to remove the growing point of the side shoot after it had produced two leaves. In doing this, additional leaf area was provided the plant without increasing the number of growing points.

TABLE I—EFFECTS OF AXILLARY FOLIAGE ON YIELD OF TOMATOES GROWN UNDER FIELD CONDITIONS* (SUMMER 1946 — AVERAGE PER TEN PLANTS, VARIETY — MASTER MARGLOBE)

Treatment	No. of Fruit Harvested	Increase or Decrease Due to Treatment (Per Cent)	Total Weight of Fruit (Gms)	Increase or Decrease Due to Treatment (Per Cent)	Average Weight of Fruit (Gms)	Increase or Decrease Due to Treatment (Per Cent)
Controls	279	—	40,397	—	145	—
One axillary shoot	315	+12.9	45,284	+12.1	144	−0.69
Two axillary shoots	331	+18.6	45,857	+13.5	139	−4.14

*Axillary foliage allowed to remain beneath first and second clusters only.

FIELD EXPERIMENT — SUMMER 1946

Since a poor set many times results on the first and second clusters of early field grown tomatoes it was deemed worthwhile to try to affect a greater set on these clusters by use of axillary foliage.

The plants were subjected to three treatments. Each treatment consisted of four replications of five plants each. They were staked and trained to a single stem. In group I, the controls, all axillary shoots were removed. In group II, one axillary shoot, bearing two leaves, was allowed to remain immediately below each of the first and second clusters. In group III, two axillary shoots, each bearing two leaves, were allowed to remain below each of the first and second clusters.

A very good set resulted on the first and second clusters of plants of all groups, and there was no marked difference in set between any of the treatments. However, on later clusters those having axillary foliage gave greater set resulting in an increased yield as shown in Table

[1]Contribution from the Department of Horticulture, Missouri Agricultural Experiment Station Journal Series No. 1088.

I. Plants in group II, having one axillary shoot below each of the first and second clusters, gave a 12.9 per cent increase in number of fruit harvested and a 12.1 per cent increase in total weight of fruit harvested over group I, the controls. Plants in group III having two axillary shoots below each of the first and second clusters gave a 18.6 per cent increase in number of fruit harvested and a 13.5 per cent in total weight of fruit over controls. Slight decreases in size of fruit due to treatment are within limits of experimental error, and, therefore, they are insignificant.

Greenhouse Experiment — Winter 1946–47

In this experiment the plants were grown in a ground bed in the greenhouse. They were staked and trained to a single stem as in the field experiment. The plants were transplanted to the bed on November 2.

TABLE II—Effects of Axillary Foliage on Yield of Tomatoes Grown Under Greenhouse Conditions (Winter 1946–1947, Average Per Ten Plants, Variety — Break O'Day)

Treatment	No. of Fruit Harvested	Increase or Decrease Due to Treatment (Per Cent)	Total Weight of Fruit (Gms)	Increase or Decrease Due to Treatment (Per Cent)	Average Weight of Fruit (Gms)	Increase or Decrease Due to Treatment (Per Cent)
Controls............	190	—	31,998	—	154.8	—
One axillary shoot...	233	+22.6	42,313	+32.1	181.6	+17.3
Two axillary shoots..	234	+23.1	43,875	+37.1	187.5	+21.1

The plants were divided into three groups of 18 plants each. In group I, the controls, all axillary shoots were removed. In group II, the axillary shoot immediately below each cluster was allowed to remain. In group III, the first two axillary shoots below each cluster were allowed to remain. Each axillary shoot was decapitated after having produced two leaves. A total of eight clusters were allowed to develop on each plant.

Plants in both groups II and III set more fruit per cluster and produced larger fruit which gave rise to a marked increase in yield as shown by Table II. Plants in group II, having one axillary shoot immediately below each cluster, gave a 22.6 per cent increase in number of fruit and a 17.3 per cent increase in size of fruit over the controls. This increase in number of fruit and increase in size of fruit gave an increase in total weight of 32.1 per cent over the controls. Plants in group III, having two axillary shoots below each cluster, gave a 23.1 per cent increase in number of fruit and a 21.1 per cent increase in size of fruit, which together, gave rise to an increase of 37.1 per cent in total weight over the controls.

Summary and Conclusions

The results of these studies indicate that the foliage of decapitated axillary shoots augmented the yield of tomatoes. An increased set resulted both in the field and in the greenhouse. There was also an in-

crease in size of fruits on the greenhouse grown plants. Perhaps an increase in size would have resulted in the field also if axillary foliage was allowed to remain below all clusters instead of only the first and second.

The axillary shoot immediately below the cluster, the one which grows most rapidly, appears to account for most of the increase in yield. One axillary shoot below the cluster gave nearly as high an increase in yield as did two.

This method of pruning should prove very worthwhile to the grower of greenhouse tomatoes and perchance, also, in outdoors culture where the plants are trained to a single stem, for it is not difficult to do this and a substantial increase in fruit yield may be expected.

Effects of Milk Products on the Growth and Yields of Vegetables[1]

By V. E. IVERSON and LEON H. JOHNSON, *Montana Agricultural Experiment Station, Bozeman, Mont.*

IN preliminary tests (1) applications of skim milk to tomato transplant soils resulted in plants with larger, more fibrous root systems, larger and taller stems with greater leaf areas and increased early and total yields.

In 1947 more extensive and detailed experiments were conducted to determine the effects of transplant soil applications of skim milk and buttermilk upon the growth and yields of tomatoes and onions, and to determine the nature of these effects upon plant growth. The most desirable commercial fertilizer treatments for transplants, determined by previous experiments, were included in the tests and were applied alone and in combination with the milk products for comparison. All treatments were made prior to field planting.

MATERIALS AND METHODS

Field experiments consisted of a 6 by 6 latin square with 10 plants per treatment in each replication for tomatoes and a similar arrangement with 20-foot rows for onions. Tomatoes were spaced 2 by 4 feet in the field, pruned to two stems and staked. Onions were spaced 4 inches apart in the row with 2 feet between rows. All plots were irrigated with a low pressure sprinkler system.

The six treatments applied to the transplant soils in the greenhouse were as follows:

1. Control.
2. Skim milk — 150 cubic centimeters per 4-inch pot of soil over a period of 5 weeks; applying 10 cc the first week, 20 cc the second, 30 cc the third, 40 cc the fourth and 50 cc the fifth week. For onions, 18 times the above amounts were applied per flat of soil, beginning at the time of seeding. The skim milk was applied directly upon the soil in which the transplants were growing.
3. Buttermilk — same rate and method of application as for skim milk in 2.
4. Commercial fertilizers — the best rate and method of application as determined by previous experiments consisting of the following: 1 gram sulphate of ammonia plus 1 gram of treble superphosphate applied at time of "pricking off" to each 4-inch tomato pot soil and applied to seedling flats in 18 times the above amount for onions, followed by 1 gram of sulphate of ammonia per pot for tomatoes and 18 grams for onions applied the day previous to field transplanting as a "starter".
5. Skim milk and commercial fertilizers — treatments 2 and 4 combined.
6. Buttermilk and commercial fertilizers—treatments 3 and 4 combined.

[1]Contribution from Montana State College, Agricultural Experiment Station, Paper No. 200 Journal Series.

The transplant soil mixture consisted of 25 per cent sand, 25 per cent well-rotted manure and 50 per cent garden loam soil. The mixture had the following chemical analysis:

pH—7.2
K x 10^5—300
N—0.67 per cent total
P—27 ppm available (CO_2 method)

Previous tests have indicated high available potassium in all local soils.

The field plot soil was Huffine silt loam with the following chemical analysis:

pH—7.1
K x 10^5—24
N—.16 per cent total
P—1.3 ppm available (CO_2 method) .07 per cent total.

The varieties of vegetables studied were Bonny Best tomatoes, Yellow Globe Danvers and Sweet Spanish (Utah strain) onions.

Data were analyzed by "analysis of variance" for a latin square arrangement of plots.

Results

Summaries of experimental data for the three crops are given in Tables I, II, and III. In considering the data for tomatoes the following points are pertinent: All of the experimental plots were located at Bozeman, Montana, at an altitude of nearly 5,000 feet, with a short growing season and low night temperatures; therefore the data given for total yield of ripe fruit would be somewhat comparable to early yields in a favorable tomato section. The columns for green fruit were based upon the green fruit left on the vines after the first killing frost in the fall.

TABLE I—The Effects of Transplant Soil Treatments of Skim Milk, Buttermilk and Commercial Fertilizer on the Yields of Bonny Best Tomatoes*

Treatment	Ripe No. 1		Ripe No. 2		Total Yield Ripe		Green Fruit	
	Number	Weight (Ounces)	Number	Weight (Ounces)	Number	Weight (Ounces)	Number	Weight (Ounces)
Check	33.0	137.0	3.2	13.5	36.2	150.5	246.8	711.8
Skim milk	40.6	197.5	3.6	18.8	44.6	216.3	235.8	762.1
Buttermilk	36.1	178.5	3.0	13.3	39.1	191.8	236.5	713.1
Commercial fertilizers	46.1	233.5	6.3	30.5	52.4	264.0	226.1	694.1
Skim milk and commercial fertilizers	55.6	258.0	2.8	14.7	58.4	272.7	231.8	711.2
Buttermilk amd commercial fertilizers	46.1	241.7	4.7	19.5	50.8	261.2	245.5	785.2
L. D. 5 per cent level	13.73	53.48	N.S.	N.S.	13.85	52.17	N.S.	N.S.
L. D. 1 per cent level	N.S.	72.95	N.S.	N.S.	N.S.	71.15	N.S.	N.S.

*Mean yields per plot (10 plants).

An analysis of Table I indicates that both skim milk and commercial fertilizers, used singly or in combination, when compared with no treatment resulted in significant increases in weights of No. 1 ripe and

total ripe fruit. No significant differences in green fruits resulted from the treatments which would indicate that the treatments resulted primarily in increased early yields. Table I also indicates that buttermilk was not quite as beneficial as skim milk. This was probably due to better penetration of the skim milk in the soil. Buttermilk tended to remain near the soil surface and form a hard surface crust above the tomato root zone.

Preliminary data on tomato fruit quality indicate that both milk treatments and commercial fertilizers result in more fleshy fruits with fewer seeds.

An analysis of Table II for Yellow Globe Danvers onions indicates that skim milk, buttermilk and commercial fertilizers, used either singly or in combination, when compared with no treatment, resulted in highly significant increases in both No. 1 and total yields of onions. Table III for sweet Spanish onions indicates that applications of either

TABLE II—THE EFFECTS OF TRANSPLANT SOIL TREATMENTS OF SKIM MILK, BUTTERMILK AND COMMERCIAL FERTILIZERS ON THE YIELDS OF YELLOW GLOBE ONIONS*

Treatment	Yields (Ounces)		
	Number 1	Number 2	Total
Check	322.3	50.5	372.8
Skim milk	394.8	56.8	451.6
Buttermilk	424.8	42.2	467.0
Commercial fertilizers	393.0	50.8	443.8
Skim milk and commercial fertilizers	414.8	56.8	471.6
Buttermilk and commercial fertilizers	402.5	54.6	457.1
L. D. 5 per cent level	43.64	N.S.	38.90
L. D. 1 per cent level	59.52	N.S.	53.06

*Mean yields per plot (20-ft. row).

TABLE III—THE EFFECTS OF TRANSPLANT SOIL TREATMENTS OF SKIM MILK, BUTTERMILK AND COMMERCIAL FERTILIZERS ON THE YIELDS OF SWEET SPANISH ONIONS*

Treatment	Yields (Ounces)		
	Number 1	Number 2	Total
Check	433.5	112.0	545.5
Skim milk	554.5	147.8	702.3
Buttermilk	536.1	123.0	659.1
Commercial fertilizers	486.0	130.1	616.1
Skim milk and commercial fertilizers	569.3	162.8	732.1
Buttermilk and commercial fertilizers	508.8	199.2	708.0
L. D. 5 per cent level	65.5	N.S.	63.89
L. D. 1 per cent level	89.4	N.S.	87.14

*Mean yields per plot (20-ft. row).

skim milk or buttermilk resulted in highly significant increases of No. 1 yields, and that applications of skim milk, buttermilk or commercial fertilizers resulted in highly significant increases in total yields. Of the single applications, skim milk resulted in the largest per cent increase.

To determine the specific effects of milk products upon transplant soils, preliminary experiments were conducted. The following chemi-

cal analysis of untreated soil offers an interesting comparison with the analysis of the soil which had the 5 weeks skim milk treatments:

	Check Soil	*Skim Milk Treated Soil*
pH	7.2	6.9
K x 10^5	300	700
N.	.67 per cent total	.63 per cent total
P.	27 ppm available (CO_2 method)	27 ppm available (CO_2 method)

The effects of milk products on the biological activity of transplant soils are summarized in Table IV. The method of Neller (2) was used in the determination of the carbon dioxide produced by the soil organisms. The top 2 inches of soil were removed from each pot immediately prior to the determination. The soil was well mixed and an amount of approximately 125 grams was used in the analysis. After the carbon dioxide had been determined, the soil sample was spread out on a large watch glass and allowed to dry for 72 hours. All calculations of the amounts of carbon dioxide produced were based on the air dried weight of the soil.

The results of this preliminary experiment (Table IV) indicate a remarkable increase in biological activity resulting from "milk" treatments. Further studies along this line are being conducted. The additional available nutrients present in the added milk, together with the greatly increased biological activity, may at least partly explain the growth and yield effects discussed in this paper.

TABLE IV—THE EFFECTS OF TRANSPLANT SOIL TREATMENTS OF SKIM MILK AND BUTTERMILK ON THE BIOLOGICAL ACTIVITY OF THE SOIL AS INDICATED BY CARBON DIOXIDE EVOLUTION*

Weeks From Time of First Treatment	Mg CO_2/100 Grams Air Dry Soil/45 Minutes		
	Check (No Treatment)	Skim Milk	Buttermilk
1st week	0.38	1.65	13.75
2nd week	—	8.10	6.26
3rd week	—	11.45	9.08
4th week	—	14.55	18.65
5th week	0.36	17.15	28.40

*Means of two samples.

SUMMARY

1. Transplant soil treatments of skim milk and commercial fertilibers, used either singly or in combination, when compared with no treatment, resulted in statistically significant increases in No. 1 ripe and total ripe Bonny Best tomatoes.
2. Skim milk, buttermilk and commercial fertilizers, used either singly or in combination, when compared with no treatment, resulted in highly significant increases in both No. 1 and total yields of Yellow Globe Danvers onions.
3. Applications of either skim milk or buttermilk, when compared with no treatment, resulted in highly significant increases of No. 1 yields, and applications of skim milk, buttermilk or commercial fertili-

zers, when compared with no treatment, resulted in highly significant increases in total yields of Sweet Spanish onions.

4. Preliminary studies have indicated that soil applications of milk products resulted in some changes in the chemical composition of the soil and a substantial increase in biological activity.

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Early and Total Yields of Tomatoes as Affected by Time of Seeding, Topping the Plants, and Space in the Flats[1]

By Charles B. Sayre, *New York State Agricultural Experiment Station, Geneva, N. Y.*

This paper is a report of two years' results of a factorial experiment, comparing three dates of sowing tomato seed and four methods of growing the plants. Each treatment was replicated four times and the entire experiment was duplicated in two locations, Geneva and Albion, which are 90 miles apart, and two of the treatments with the three dates of sowing seed were also repeated at Fredonia, which is 150 miles from Geneva. The John Baer variety was used at all three locations. Results were measured by differences in early yields and in total yields of red ripe tomatoes for canning. Six pickings of all the ripe fruit were made at each location each season and the first two harvests were classed as the "early" yield.

Factorial summaries of the yield records from the three experiment fields in 1946 and 1947 were prepared by Dr. M. T. Vittum and are presented in Tables I and II respectively.

TABLE I—Factorial Analysis of Four Methods of Growing and Three Dates of Seeding John Baer Tomatoes (1946)*

Treatments	Average Yield (Tons Per Acre)					
	Geneva		Albion		Fredonia	
	Early	Total	Early	Total	Early	Total
Methods of Growing (Average of three dates of seeding by four replicates):						
Regular (108 plants per flat)	2.60	11.80	3.48	17.82	1.34	9.60
Topped (tops cut off at height of 9 inches)	2.02	12.18	3.67	17.66	2.20	8.55
Deep Flat (33 per cent more soil)	2.81	10.86	3.71	18.00	1.61	9.33
More Space (80 plants per flat)	2.66	11.46	3.70	17.59	—	—
L.S.D. due to method of growing 19:1	0.44	N.S.	N.S.	N.S.	0.37	N.S.
Dates of Seeding (Average of All Methods of Growing by four replicates):						
March 11	2.28	11.62	3.24	17.30	1.68	9.15
March 25	2.83	11.88	3.81	17.96	2.00	9.48
April 8	2.46	11.23	3.86	18.04	1.47	8.85
L.S.D. due to date of seeding 19:1	0.39	N.S.	0.51	N.S.	0.37	N.S.
Interaction between methods and dates	N.S.		N.S.		N.S.	

*Transplanted to field May 24 at Geneva; May 27 at Albion; May 23 at Fredonia. Plants topped May 18.

Comparison of Methods of Growing Plants

The usual method of producing tomato plants for the canning crop growers in New York is to sow the seed in greenhouses some time in March and prick off the seedlings into flats in which the plants are grown until transplanted to the field. Usually 108 seedlings are set per flat, which measures 14 by 20 inches and 2¾ inches deep. This method was used in growing the plants designated "Regular" in Tables I and II.

[1]Journal Paper No. 752, New York State Agricultural Experiment Station.

TABLE II—FACTORIAL ANALYSIS OF FOUR METHODS OF GROWING AND THREE DATES OF SEEDING JOHN BAER TOMATOES (1947)

Treatments	Average Yield (Tons Per Acre)					
	Geneva		Albion		Fredonia	
	Early	Total*	Early	Total	Early	Total
Methods of Growing:						
Regular (108 plants per flat)	1.03	7.01	0.37	3.72	2.73	9.48
Regular Topped	2.48	9.55	1.21	4.68	4.15	10.84
Deep Flat (33 per cent more soil) topped	2.70	9.71	1.06	3.79	—	—
More Space (80 plants) topped	2.97	10.05	1.53	4.74	—	—
L.S.D. due to methods 19:1	0.43	1.16	0.36	N.S.	0.75	1.28
Dates of Seeding:						
March 10	1.94	8.22	1.07	4.44	3.27	9.61
March 25	2.32	9.15	0.98	4.24	3.74	10.93
April 8	3.49	9.87	1.08	4.01	3.30	9.94
L.S.D. due to date of seeding 19:1	1.12	2.33	N.S.	N.S.	N.S.	N.S.
Interaction between methods and dates	N.S.		N.S.		N.S.	

*Last picking Sep 10. Early frost.
Frequent heavy rains kept soil too wet for transplanting until June 11 at Geneva, June 18 at Albion, and June 19 at Fredonia. Plants topped May 22.

In the treatment designated "Regular Topped", the plants were grown in the same manner as the "Regular" lot, but when these plants were about 8 to 9 inches tall, they were "topped". This consisted in cutting off the tops of the plants so that the terminal growing point was removed. This checked further elongation of the main stem and stimulated the development of the lower axillary buds, thus producing a compact, branched plant, instead of one having a single long stem.

In the treatment designated "Deep Flat", the plants were grown in flats 1 inch deeper than the usual flat. This gave the plants 33 per cent more soil without requiring more surface area in the greenhouse and coldframes. It was thought that this might benefit particularly the early seeded lots which would be held longer in the flats.

In the treatment designated "More Space", only 80 plants were set per flat. This required 25 per cent more flats and more space in the greenhouse and coldframes and increased the cost of the plants proportionately.

Comparing these different methods of growing the plants in 1946, Table I, the results were contradictory. At Albion, where the highest yields were obtained, there were no significant differences in yields due to the different methods of growing the plants. At Geneva, there were significant differences in early yields but not in total yields. The "topped" plants produced a significantly lower early yield than any of the other treatments, but there were no significant differences due to spacing or to depth of flat. At Fredonia, the "topped" plants produced significantly higher early yields than any other treatment, which was exactly the reverse of the results obtained at Geneva.

The original plan had been to repeat the same treatments at the three locations in 1947. However, during the entire month of May, rains occurred so frequently that the fields could not be prepared for planting. When it was evident that it would not be possible to transplant the tomatoes to the fields until some weeks after the scheduled time (May 25th) it was decided that the plants could be held in best condition for transplanting if they were topped. Previous experiments

(1) had indicated that this would be advisable when the plants would have to be held for some time. Consequently, the more widely spaced and "deep flat" lots as well as the "regular" lots were topped, leaving only one "regular" lot unpruned. In other words, in 1946 there was one lot of topped plants and three not topped, in 1947 three lots were topped and only one not topped.

In 1946 the plants were topped with a power lawn mower, by mounting the mower 9 inches above the flats and then sliding the flats under the revolving blades. But in 1947, the plants were about 12 inches tall when it was decided to cut them back to 9 inches. At this height, many of the tops bent over as they were passed under the power lawn mower and were not cut off. Consequently the 1947 plants were topped with hedge clippers.

At each location in 1947, the topped plants produced significantly larger early yields than the plants that were not topped. The total yields from the topped plants were also significantly greater at Geneva and Fredonia. The unpruned plants had grown very tall and leggy by the time they could be set in the field, while the topped plants were compact and bushy and stood transplanting much better.

Giving the plants more space in the flats did not affect the yields significantly in 1946 at any location. In 1947 the plants had to be held in the flats 3 weeks longer and again the differences in total yields were not significant; but there was a significant increase in early yield at Geneva, due to wider spacing in the flat.

There was no significant gain due to more soil in deeper flats at any location either season.

Comparison of Seeding Dates

In no case did the earliest seeding date give the highest early yields. In 1946 at Geneva and at Fredonia, the highest early yield was obtained from seed sown March 25th, and at Albion this seeding date gave as good results as the April 8th seeding. In 1947, plants from the latest seeding date (April 8) produced significantly larger early yields at Geneva than plants grown from seed sown 2 weeks or 4 weeks earlier. Each lot of plants was approximately 3 weeks older at transplanting time than the corresponding lot in 1946, because transplanting had to be postponed in 1947 due to wet fields (Tables I and II). At Albion and at Fredonia in 1947 there were no significant differences due to date of seeding. Consequently, the last seeding date, which would require less labor in caring for the plants, less greenhouse heat, and would occupy the greenhouse and cold frames for a shorter period, would give the most economical returns.

Summary and Conclusions

Two years' experiments comparing four methods of producing tomato plants and three dates of sowing the seed have indicated that where the plants are to be transplanted to the field about May 25th or later, there is no increase in early or total yields of tomatoes from sowing seed earlier than March 25th, and that seed sown as late as April 8th may give as large or larger yields than earlier seeding. The

latter plants also cost less. Topping the plants at a height of 9 inches will prevent the plants from becoming too leggy and will produce more compact plants that stand transplanting better. These results were similar to the results of previous experiments indicating that topped plants will also produce larger early yields if transplanting is unduly delayed. In this experiment, giving the plants 25 per cent more space in the flat by setting 80 as compared with 108 seedlings per flat gave a slight increase in early yields when the plants had to be held 3 weeks longer in the flats, but made no difference when the plants were transplanted at the normal time. Growing the plants in deeper flats with 33 per cent more soil did not affect the yields either season.

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The Value of a "Hormone" Spray for Overcoming Delayed Fruit Set and Increasing Yields of Outdoor Tomatoes

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TOMATO growers frequently experience difficulty in obtaining satisfactory set of fruit on the first flower clusters. Poor fruit set is generally ascribed to cold cloudy weather which may prevail in the spring and early summer months. Production of early fruit is a prime objective of the tomato grower in Michigan and like areas since fresh market supplies are generally light, demand is great, and prices are high until late summer or early autumn. In such marginal areas having short, cool seasons, it is necessary that fruit set on the first clusters if a profitable tomato crop is to be matured before frost. In efforts to harvest tomatoes when the price is high, growers generally resort to early varieties which have a greater capacity to set fruit in cool weather but produce a small tomato of poor quality. Other gardeners go to considerable expense to grow large plants in the greenhouse which have the fruit set on the first clusters prior to field transplanting. Recent report have indicated the value of plant growth regulators ("hormones") as sprays for improving fruit set and yields on greenhouse tomatoes when sunlight is deficient (8, 14). They have suggested the possibility that delayed fruit set on the early flower clusters of outdoor tomatoes during adverse weather can be overcome by the use of hormone sprays.

METHODS

Grower practices were followed in producing or obtaining tomato plants. For a source typical of those used by the market gardener for producing early fruit, the plants were started and grown in the Michigan State College vegetable greenhouse, maintained at 60 ± 1 degrees F night temperature. Plants used in the late canning plots were shipped in from Georgia. The hormone spray was applied to the plants in the field when flowers first appeared on the crown clusters and twice thereafter to subsequent flower clusters at approximately weekly intervals. The spray, at 50 pounds pressure, was directed on to the inflorescences by means of a quart size "shur-shot" sprayer,[1] equipped with a nozzle producing an enveloping conical mist. The hormone chemical used in all experiments herein reported consisted of 25 parts per million of para-chlorophenoxyacetic acid[2] in water solution. Recently, published (8) and unpublished (3, 6) reports indicate that this chemical is one of the most effective for setting and maturing tomato fruit.

[1]Manufactured by the Steiner Sales Co., 225 W. Chestnut St., Chicago 10, Illinois.

[2]Grateful acknowledgment is extended to Lawrence Southwick of the Dow Chemical Company for supplying liberal quantities of this chemical.

An Early Crop of Victor and Rutgers

Seed of the Michigan State College strain of Victor and Stokes' Rutgers were sown April 1. Seedlings were transplanted into 4-inch clay pots April 18, and removed to a cold frame for hardening on May 19. Field transplanting took place on May 27. Plants were spaced at 3 feet in rows which were 5 feet apart. The soil type was a Hillsdale sandy loam that had received a 10-ton per acre application of stable manure and 800 pounds per acre of 3–12–12 fertilizer which was broadcast and disked in, following spring plowing. Approximately 500 potted plants of each variety were set in four randomized plots containing 120 plants each. Flowers first appeared on the Victors on June 9. At this time, the plots were split, the flower clusters on half the plants were sprayed, and an equal number left unsprayed as controls. Similarly, 5 days later on Rutgers when flowers appeared, the plots were divided, the flower clusters on half the plants sprayed, an equal number remaining as controls. Harvesting of ripe fruit from treated plants of Victor began on July 25 and on July 30 for Rutgers. The first fruits were picked from the controls of both varieties on the same date—August 6. Weights of only marketable fruit were recorded.

The comparable amounts of fruit harvested during the entire season from treated and control plants of the two varieties are presented in Fig. 1. The varietal contrast is striking. Spraying the first three

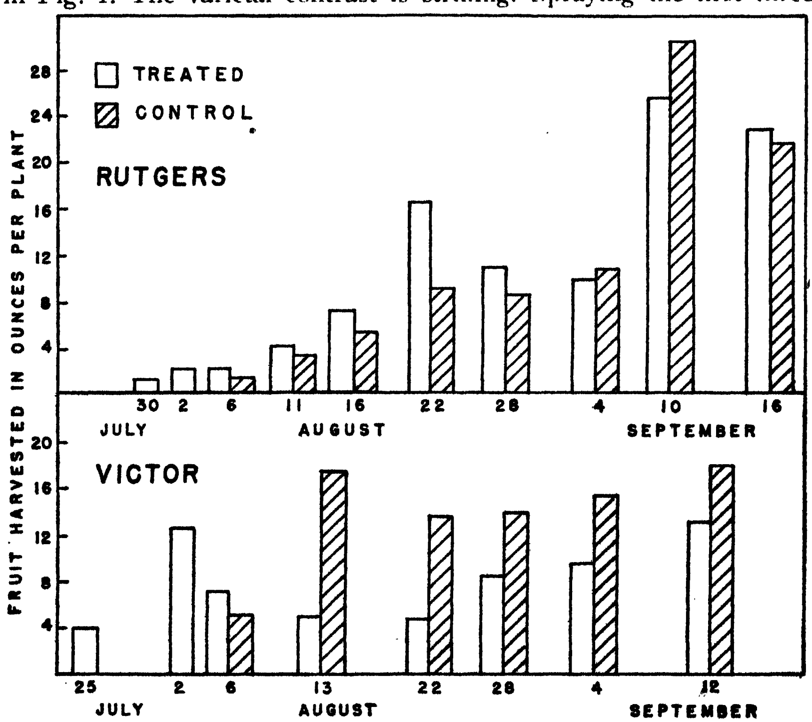

Fig. 1. Average weight of fruit harvested in ounces per plant, throughout the 1947 season, of treated versus control Victor and Rutgers tomatoes.

flower clusters on Victor produced over a pound of fruit per plant before any tomatoes were harvested from plants not treated. The first ripe fruit were picked 12 days earlier. This flush of early fruit, however, greatly inhibited vegetative growth and resulted in a considerable reduction in yield compared with controls of the same variety later in the season. Such correlative inhibitions can, however, be partially overcome by timely fertilization (7, 12). From treated Rutgers plants, fruit were picked 7 days earlier than from untreated plants of the same variety, as a result of the hormone spray. Compared with Victor the increase in yield of early fruit above the controls was much less, but treated plants continued throughout the season to produce a total of fruit equivalent to more than that harvested from the controls. It is of interest that two pickings were made from treated Rutgers before any fruit were harvested from controls of the Victor variety — this in view of the fact that Victor is considered one of the earliest and Rutgers one of the latest tomatoes.

Fig. 2 represents the authors' attempt to convert the fruit harvest

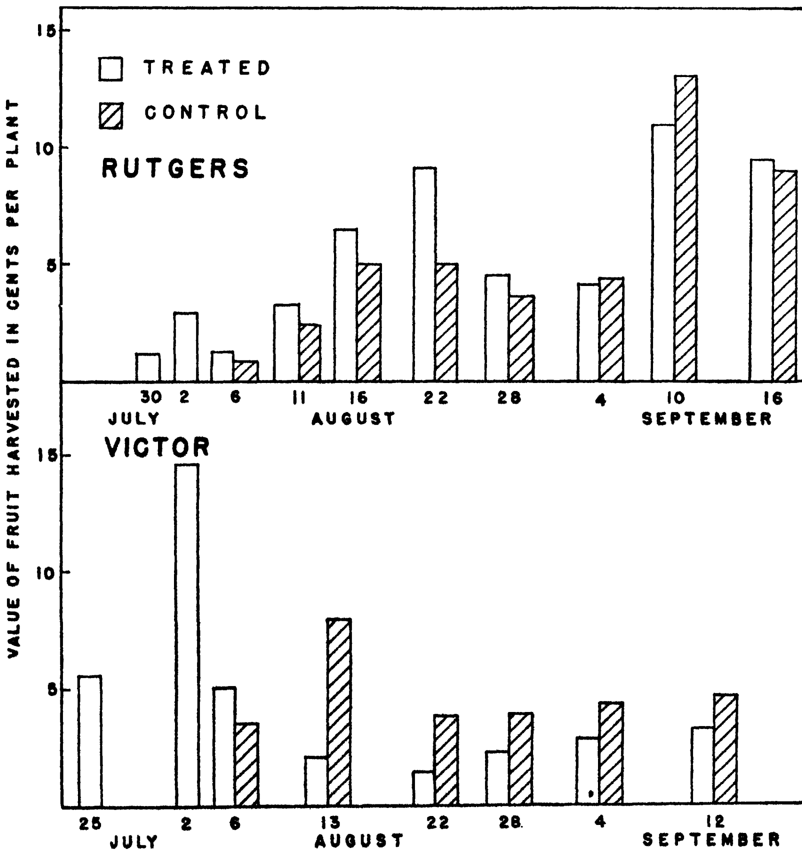

Fig. 2. Average value of fruit harvested in cents per plant, throughout the 1947 season, of treated versus control Victor and Rutgers tomatoes.

into value and thus portray the actual dollar differences in seasonal yields. Values on a per plant basis were ascertained by multiplying yields by the average current prices paid for tomatoes on the farmers' markets located in Detroit and Benton Harbor. According to the figure, treated Victors produced tomatoes worth 20 cents per plant prior to harvesting any fruit from the controls. This was the equivalent of over $400 when converted to an acre basis.

Total yields and values for the season on treated and control plants of the two varieties are summarized in Fig. 3. Treatment of the Victor variety yielded 30 per cent less than for those not treated. However, when interpreted as cents per plant, the treated gave an income of a third more. This value is probably underestimated since a much larger proportion of fruit on the control plants was harvested late when there would be no demand for a low quality fruit of the Victor type. For Rutgers the season's total production was greater from treated plants. The differences were accentuated when yield was converted to value. That is, more fruit from treated plants ripened early, which, in turn, commanded a higher price. The differences in quantity of early harvested fruit from treated versus untreated Rutgers did not, however, approach in magnitude those differences for Victor.

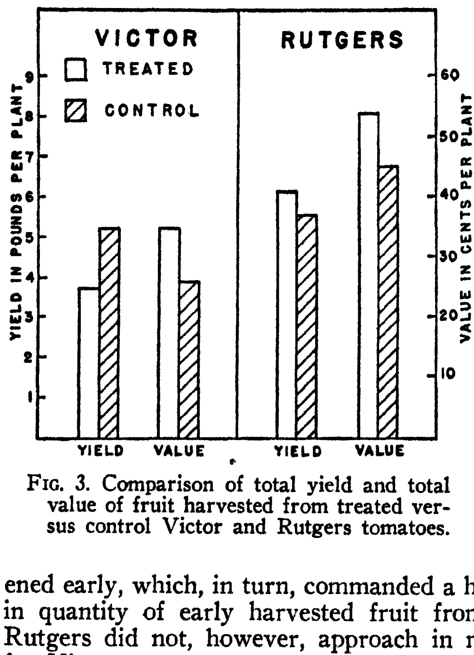

FIG. 3. Comparison of total yield and total value of fruit harvested from treated versus control Victor and Rutgers tomatoes.

A CANNING CROP OF RUTGERS[3]

The plants in this test were shipped in from Georgia and set into the field on June 16. A 3- by 6-foot spacing of plants was used. The first flowers appeared on the crown clusters July 9. On this date four paired plots, each of the paired members with 20 plants, were laid out, and the flower clusters on half the plants (one of the members of the pair in each case) were sprayed, the other left as a control. Subsequent sprays were applied July 18 and 28 to the second and third flower clusters, respectively. Ripe fruit were picked for the first time on August 18, and in Fig. 4 are the yield data of the actual fruit harvested from the four pairs of plots in the first six pickings which were made from August 18 to September 5. Fruit resulting from treatment

[3]The authors are indebted to Mr. B. E. Clark for his assistance in conducting this phase of the study.

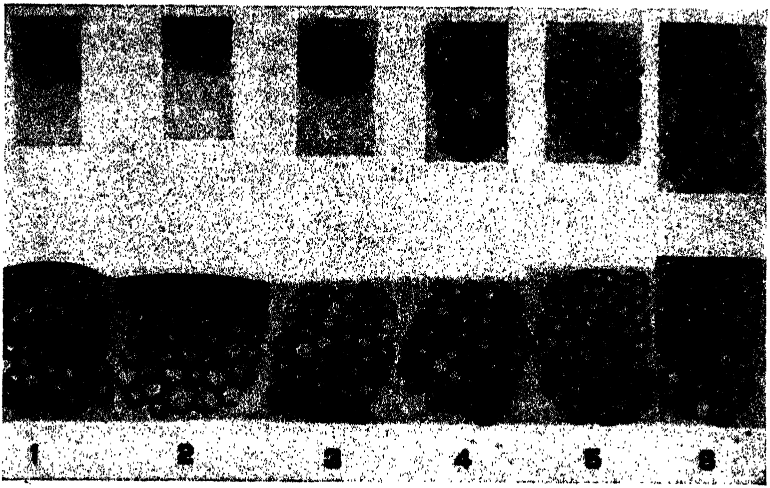

FIG. 4. Total crop of Rutgers tomatoes from the first six pickings arranged from left to right in order of harvest. Above — controls; below — first three flower clusters sprayed with 25 ppm p-chlorophenoxyacetic acid.

were solid, well shaped, and of good color, and were in all respects as marketable as those harvested from the controls. The treated tomatoes differed only in that they were larger in size and many were seedless in the early pickings. Seedlessness disappeared, however, in later harvests.

Table I records the season's complete harvest of fruit, including the last three pickings. The increase in total yield, as a result of the treatment, came largely from differences in early yield, although treated plants consistently yielded more fruit than controls even in the later

TABLE I—EFFECT OF HORMONE SPRAYS ON FRUITING OF RUTGER'S TOMATOES GROWN FOR CANNING

	Mean Yield of Fruit (Lbs/20 Plants)	Mean Size of Fruit (Ounces)	Per Cent Increase	
			Yield	Size
First to Third Pickings (Aug 18 to Aug 25)				
Treated	16.25**	6.6	415	35
Controls	3.15	4.9	—	—
Fourth to Sixth Pickings (Aug 28 to Sep 5)				
Treated	22.20*	5.9	42	18
Controls	15.55	5.0	—	—
Seventh to Ninth Pickings (Sep 10 to Sep 20)				
Treated	155.40	6.0	13	9
Controls	133.35	5.5	—	—
All Pickings (Aug 18 to Sep 20)				
Treated	193.90*	6.0	27	11
Controls	152.05	5.4	—	—

*Significant (.05).
**Highly significant (.01).

harvests — this, in spite of the fact that the flower clusters producing the fruit toward the end of the season were not sprayed with the hormone chemical. The increase in fruit size was almost as striking as that for yield. These differences in the treated and control series also continued throughout the season. Total yields, expressed in tons to the acre of marketable fruit, showed approximately 8 for the controls and over 10 tons for treated plants. Treated fruit averaged a half ounce larger in size.

Discussion

To date, the practical value of hormone sprays for improving the set of fruit on outdoor tomatoes has been questioned (4, 9), and reportedly their use for increasing total yields has met with little success (1, 15). Accordingly, in view of the striking results herein reported, one is perhaps justified in attempting to ascertain the present cause of poor fruit set, and such a remarkable response to the hormone spray.

An inadequate light supply (8, 14) is credited as the cause of poor fruit set in greenhouse tomatoes. Examination of Table II[4] shows that

TABLE II—Average Daily Totals of Radiation (Gm Cals per Cm^2)

Recording Station	March	April	May	June
East Lansing, Michigan	264	374	356	480
State College, Pennsylvania	294	411	455	507
New York, New York	295	385	459	487
Nashville, Tennessee	308	420	472	547
Madison, Wisconsin	314	406	470	523
Washington, D. C.	320	409	485	513
Blue Hill, Massachusetts	330	395	462	511
Lincoln, Nebraska	377	419	493	572
Davis, California	397	601	685	760
Tooele, Utah	446	528	687	814

East Lansing, Michigan, (the location of the experiments herein reported) receives less sunlight during the crucial months of April, May, June, and July than any other station where long-time records have been compiled. Too little sunlight was perhaps a contributing factor in causing a poor set of fruit.

According to recent detailed and comprehensive studies of the tomato plant in controlled environments, as reported by Went and Cosper (13), the critical factor insofar as fruit setting is concerned is night temperature. Earlier workers suggested this relationship but in less exacting terms (10, 12). The optimal range according to Went and Cosper is 59 degrees to 68 degrees F (15 degrees to 20 degrees C). Temperatures below 55 degrees F gave a very poor set of fruit, even on an early variety such as Earliana, with no fruiting at all on later types.

In Fig. 5, where the day-to-day average night temperatures for East Lansing are recorded for the month of June in 1947, it is obvious that

[4]Personal acknowledgment is rendered Director V. R. Gardner, of the Michigan Agricultural Experiment Station, who compiled the data on radiation in cooperation with the United States Weather Bureau.

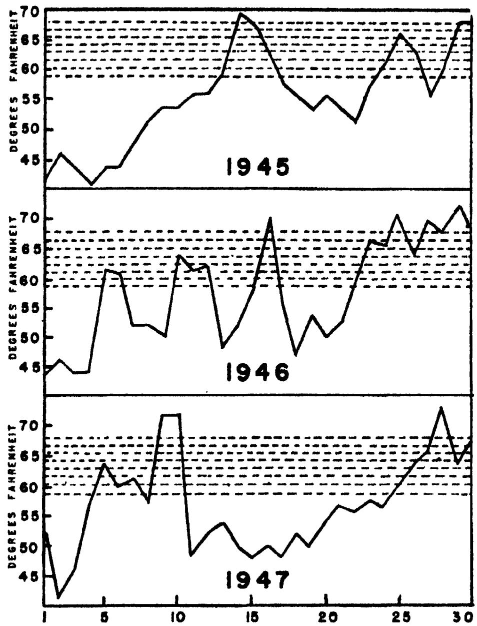

FIG. 5. Average temperatures (6:00 pm to 6:00 am) of nights in June during 1945, 1946, and 1947, in East Lansing, Michigan. (Shaded areas, 59 to 68 degrees F. represent optimal ranges for tomato fruit set — see Went and Cosper (13).

the nights were too cold for fruit to set from June 10 to June 25. Our records which showed the first flowering of the variety Victor to be on June 9 also revealed no natural fruit setting on the controls until after June 25. This effect was manifest in the harvesting dates which also recorded the first picking for the nontreated plants on August 6, compared to July 25 for plants on which the flower clusters received the hormone. The spray treatment, applied prior to, and during, the interval of cold weather, overcame the adverse effects of low night temperatures and resulted in an immediate set of fruit, irrespective of cold nights. Consequently, treated Victors ripened almost 2 weeks earlier. The first fruit from treated Rutgers were picked approximately 1 week before the controls of the same variety. This came as a result of a 5-day delay in flowering compared with Victor. With the arrival of warm nights after June 25, both varieties set fruit equally well. Again, in the test with the canning crop of Rutgers, difficulties in natural fruit setting were attributable to night temperatures which were too low even in July. Fifteen of the nights between July 1 and 25 gave an average recording of less than 59 degrees F. However, a few sporadic warm nights were sufficient to induce some fruiting on the controls.

These data on fruit setting are in agreement with the observations of Went and Cosper and lead one to surmise that, in Michigan, cold nights are a frequent cause of poor natural pollination and fruit set. The studies of Smith and Cochran (11) on optimum temperatures for pollen germination and pollen tube growth provide additional evidence for the concept.

The limitations on tomato production imposed by cold night temperatures can seemingly be overcome by the use of hormone chemicals. The significance of these deductions becomes more evident when one makes a study of weather records in upper Michigan and other northern states. They reveal that night temperatures sufficiently high to set

fruit are not seasonally prevalent until the latter part of July or early August, which does not give sufficient time to mature fruit before the September frosts. Consequently, tomato production in such areas is limited to the earliest varieties [which are the ones that set fruit at the lowest temperature (13)]; even then, crop failures are frequent. Similar temperature conditions often prevail on muck soils, at high elevations, in regions adjacent to large bodies of water, or in any locality when the crop is set out early while the nights are still cold. On muck soils difficulty, frequently encountered in getting a good set of fruit, is ascribed to the high level of soil nitrogen; however, the lower night temperatures prevailing in such areas might well be the controlling factor.

Evidence that the weather during the month of June in 1947 was not exceptional is shown by Fig. 5, wherein the day-to-day average night temperatures during June of 1945 and 1946 are also portrayed. It is not unusual for prolonged periods of cold weather to prevail through the entire month of June. The day-by-day minimum night temperatures in East Lansing, Michigan, over a 50-year period (1898 to 1947) are averaged in Fig. 6, and it is a striking fact that at no time during the month of June does the temperature get high enough at night to be in the optimal range for fruit setting.

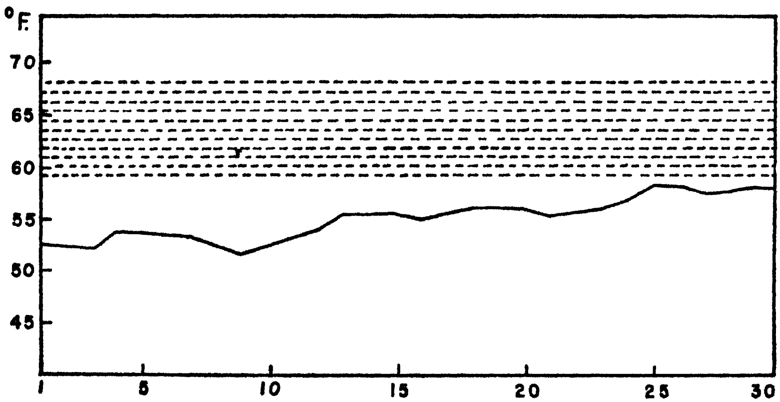

FIG. 6. Averaged minimum night temperatures in East Lansing, Michigan, during June of a 50-year period from 1898 to 1947, inclusive. (Shaded area represents optimal range for tomato fruit set).

An interesting aspect of the effect of night temperatures during June on the market supply of tomatoes later in the summer is recorded in Table III. Data were compiled from the combined reports of the Detroit and Benton Harbor farmers' markets. The index for the price break was taken as the date on which the price quoted dropped to 75 cents for a 14-pound basket. The drop was usually quite abrupt, in some years falling overnight from $1.50 a basket to $.75 or less. The $.75 a basket index was also chosen since it represents the minimal value at which many growers feel it is still profitable to grade, package, and transport tomatoes to local city markets. In the table a direct

TABLE III—EFFECT OF THE AVERAGE MINIMUM NIGHT TEMPERATURE DURING JUNE ON THE DATE OF FRESH MARKET PRICE BREAK ON TOMATOES

Mean Minimum Temperature (Degree F)	Date of Price Break	Year
60.1	Jul 29	1943
58.5	Jul 29	1941
58.1	Aug 1	1944
57.4	Aug 4	1942
54.9	Aug 14	1946
53.7	Aug 18	1947
52.6	Aug 21	1945

correlation is noted between night temperatures and the dates on which the prices broke. It appears that the time of the first flush of tomatoes on the market is predetermined by an extended period of night temperatures favorable for fruit setting in a given area. These intervals of optimal temperature preceded fruit ripening by 45 to 50 days, the usual time necessary, in Michigan, for fruit to ripen after it is set. Thus, the use of hormone sprays should help to avoid seasonal overloading of markets and characteristic price breaks by leveling out the peaks and extending the harvest period.

The time of maturity seems to be conditioned by night temperatures which control fruit setting. Variations and inconsistencies of a given tomato variety as to the number of days from field setting of plants to fruit maturity, outlined by Boswell *et al* (2) and Morrison (5), should be considered. Such data may be examined in light of the fact that when Rutgers, reportedly an 85-day tomato, was treated, fruit were harvested twice and 7 days earlier than fruit from non-sprayed Victor, a 65-day tomato. "Earliness", it appears, may be modified considerably by hormone spraying, suggesting the possibility of harvesting ripe fruit of high quality late varieties in marginal areas heretofore suited only for the production of small-fruited, early, but poor quality types. A variety of tomato may be early by virtue of its ability to set fruit at night temperatures lower than those for another variety. The data of Went and Cosper (13) and our own records showed that the time intervals from seeding to anthesis varied only a few days even when early, midseason, and late varieties were compared. This is true also of the time from fruit setting to ripening. The date when the first fruit will set, however, on different varieties may vary considerably. It is this important response controlling earliness, in turn governed by night temperatures, which can seemingly be overcome by the use of hormone sprays.

SUMMARY

Water sprays of para-chlorophenoxyacetic acid, 25 ppm, applied to the first (crown) flower clusters of field tomatoes resulted in the production of significantly more and larger early fruit. In a comparative trial involving Victor, an early variety, and Rutgers, a late variety, fruit were picked twice from treated Rutgers before any were harvested from plants of Victor which were not sprayed. Treated Victors, on the other hand, matured a pound of fruit per plant before tomatoes were picked from controls of the same variety. Spraying the first three flower clusters on plants of a late crop of Rutgers grown for canning

resulted, for the total crop harvested, in a significant yield increase of 27 per cent and a 11 per cent increase in fruit size.

The frequent occurrence in Michigan of night temperatures too low for optimum fruit setting is offered as the probable explanation for the striking results obtained. The data suggest that "hormone" spraying flower clusters may be a profitable practice in the production of early tomatoes grown in regions adjacent to large bodies of water, in northern states, on muck soils, in mountainous areas, or in any locality or season having prevailing minimum night temperatures during the normal period of fruit setting of less than 59 degrees F.

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A Rapid Objective Method for Measuring the Color of Raw and Canned Tomatoes[1]

By AMIHUD KRAMER and R. B. GUYER, *University of Maryland, College Park, Md.*, and H. R. SMITH, *National Canners Association, Washington, D. C.*

COLOR is the most evident, and probably the most important factor of quality for raw and canned tomatoes and other tomato products. A simple, rapid, and yet accurate method for determining this quality factor is therefore important. MacGillivray (3) developed a method for measuring the color of tomatoes by utilizing a disk colorimeter fitted with color disks of given Munsell notations. Essentially this method was adopted for use as a standard of quality for canned tomatoes under the Food Drug and Cosmetic Act (1). Kramer and Smith (2) obtained results similar to those of MacGillivray, indicating that "value", that is, the amount of gray or black in the color complex, is unimportant. They, therefore, suggested that results obtained by the disk method be reported as the index of red over yellow, with the higher index values indicating redder tomatoes. The disk method was considered too cumbersome and not entirely free of the human element. McCollum (4), and Kramer and Smith (2) investigated the possibility of using spectrophotometric methods for measuring color of tomatoes and tomato products. The following data show the possibilities of the spectrophotometric method as finally developed in this laboratory and its practical application to the grading of the raw and canned product.

MATERIALS AND METHODS

The commercial samples of tomatoes, tomato juice and tomato puree were obtained from processors in the Maryland area. Packs prepared especially to show wide variations in color were prepared in the horticultural laboratories from raw material grown specifically for the purpose at the plant research farm of the University of Maryland.

Reflectance measurements were made using a General Electric (Hardy) recording spectrophotometer. Pulped samples were placed in a glass cell 10 mm deep, and recorded in terms of magnesium oxide.

Transmittance measurements were made as follows:

1. *Preparation of the sample:*—Raw tomatoes were peeled, quartered, and blended in a Waring Blendor to a uniform pulp. Canned tomatoes were drained before blending. It was unnecessary, of course, to blend comminuted products such as tomato juice.

2. *Extraction:*—In each case 5 grams of the uniformly blended sample were transferred to a Waring Blendor cup, and blended for exactly 5 minutes with about 80 ml of benzol. The contents of the blended cup were then transferred to a graduated cylinder, and the volume of the benzol layer was brought up to 100 ml.

[1]Scientific Contribution L-198 of the Labeling Committee, National Canners Association. Scientific paper No. A192 Contribution No. 2100 of the Maryland Agricultural Experiment Station.

3. *Sample size:*—In most cases, 2 ml of the benzol extract were transferred to a 15 ml centrifuge tube, made up to 10 ml, and centrifuged for about 10 minutes. Occasionally, where low readings were expected, 3 ml of benzol extract were used instead of 2 ml.

4. *Readings:*—The diluted and centrifuged extract was then placed in the glass cell of the spectrophotometer, and per cent transmittance at 485 mμ was recorded, as compared to pure benzol at 100 per cent transmittance.

The organoleptic ratings presented in the tables are the average scores of five judges who rated duplicate samples of those analyzed, from 1 to 10, giving the best color a value of 1, and the poorest color a value of 10. Since each series of samples was judged separately, these organoleptic values have no absolute value, and are not necessarily comparable in all the tables.

Results

Reflectance Measurements:—The reflectance curves shown in Fig. 1 show a somewhat higher reflectance of the redder sample in the region of the spectrum approaching 700 mμ, and somewhat lower reflectance in the region centering about 550 mμ. The differences, however, are very small, and, as shown in Table I, are not so consistent as results obtained with transmittance measurements. These results are in agreement with the work of McCollum (4).

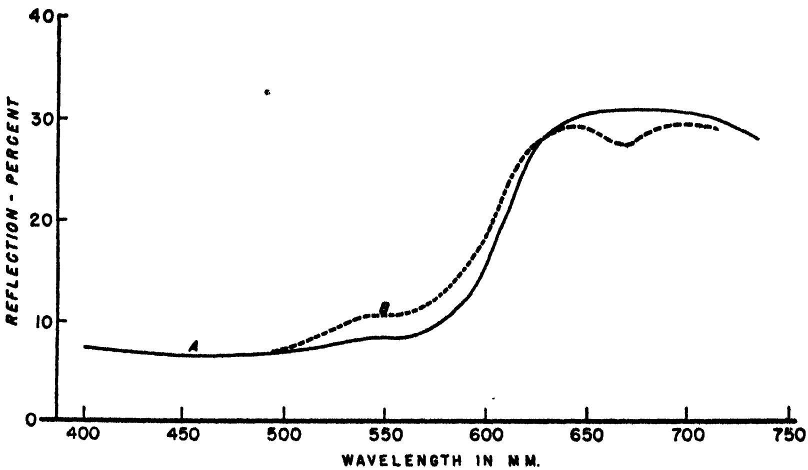

FIG. 1. Reflection curves of tomato pulp. A — redder pulp; B — poorly colored pulp

Nature of the Extracted Pigments:—Since it was intended to measure the quality factor of color in tomatoes by reference to only one narrow band of the spectrum, it was necessary first to determine whether the pigment complex in different varieties of tomatoes is essentially the same. The curves in Fig. 2 show that the extracted pigment of Rutgers, a typical red variety, shows almost an identical

TABLE I—RELATION OF COLOR RATINGS TO REFLECTANCE AND TRANSMITTANCE READINGS OF CANNED TOMATOES

Organoleptic Rating*	Transmittance Per Cent at 485mμ**	Reflectance Per Cent at 665mμ†
1.0	32	31
1.2	36	33
1.3	46	30
4.4	58	30
7.5	66	27

*1 = best color, 10 = poorest color.
**Using a Beckman spectrophotometer, 10 mm cell.
†Using a G. E. Recording spectrophotometer, 10 mm cell.

transmission curve both in respect to quality as well as concentration, to the pigment extract of Glowers Globe, an unusually "pink" variety which produces juice with a decidedly purplish cast. These samples were rated about equal organoleptically. The transmission curve for the yellow-orange Golden Jubilee variety, however, is entirely different from that of the red and pink varieties. Whereas transmission curves for the red and pink varieties exhibit a major dip centered at the wave length of 485, and another dip at 520 mμ, the yellow variety shows a major dip at 435 mμ, and a minor dip at 415 mμ.

These dips in the transmission curves for the red varieties are not entirely in agreement with the results of McCollum who reported a major dip at 510 mμ, and a minor dip at 545 mμ. This shift in the dips of about 25 mμ may be due to the different methods used in the

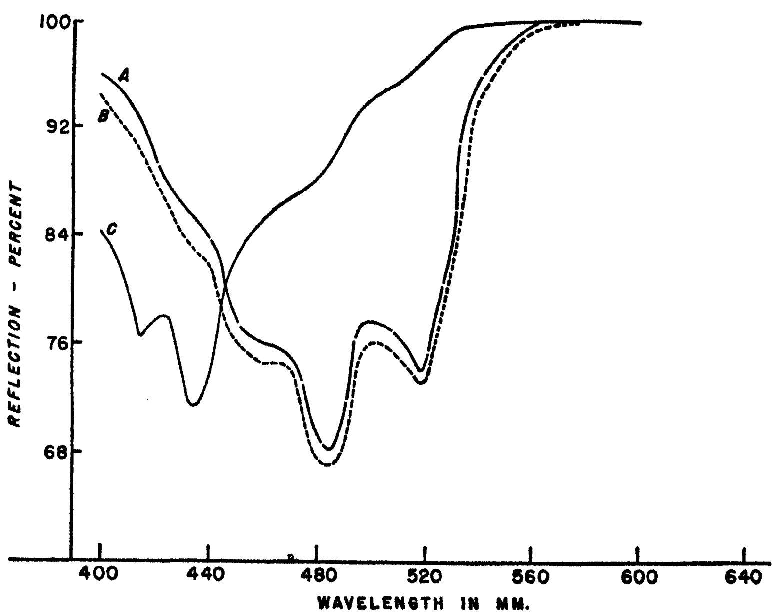

FIG. 2. Transmission curves for extracts of tomato varieties.
A — Glowers Globe; B — Rutgers; C — Golden Jubilee

extraction, or the different instruments used to obtain the transmission curves. The curves presented in Fig. 2 were obtained with a Beckman spectrophotometer and are exactly in agreement with those reported by Kramer and Smith (2) which were obtained with a Coleman Monochrometer spectrophotometer, for benzol extracts.

Measuring Instruments:—The extraction method described above was developed by using a Beckman spectrophotometer. It was realized that for practical purposes, a less costly and less sensitive instrument may be preferable. A series of tomato puree samples was measured on three different instruments, namely, Coleman, Beckman and Lumetron. The data presented in Table II indicate that results as obtained

TABLE II—Tomato Puree — Comparison of Objective Color Ratings With Different Spectrophotometers (Arranged in Order of Decreasing Color Intensity)

Instrument		
Lumestron*	Coleman**	Beckman†
50	32	28
53	38	33
55	38	35
55	38	35
57	40	37
58	43	38
59	42	38
57	42	39
59	42	39
60	42	40
60	42	41
59	45	41
61	43	41
61	45	41
61	47	42
60	46	43
61	48	43
62	47	44
62	49	45
63	49	45
64	50	46
65	51	48
66	52	49

*Per cent transmittance using filter 490.
**Per cent transmittance at 485 mμ 5 mμ slit.
†Per cent transmittance at 485 mμ 10 mm cell.

by the different instruments show almost perfect correlations. The actual values differ primarily because of differences in the slit width of the different instruments. The lowest values were obtained with the Beckman instrument where a slit width of 1.5 mμ was used. Somewhat higher values were obtained with the Coleman instrument since it was fitted with a 5 mμ slit. The Lumetron gave the highest reading, since it is a filter instrument and the filter used was about 30 mμ wide, centering about 490 mμ. The data indicate that a relatively simple and inexpensive instrument such as the Lumetron colorimeter may be used successfully in the routine evaluation of tomatoes and tomato products for color.

Sampling Procedure:—To insure reliability of results, sampling techniques are frequently as important as the method itself. For the raw product, the procedure that is to be used must be such that the sample withdrawn for analysis will reflect with reasonable accuracy the average condition of the lot. In the case of the canned product, the question of variability among cans and within the can is also important. The opinion has been expressed that the consumer objects to variability in color as much as, or more than to uniformly poor color. A determination of the variability of color may be made by measuring separately different portions of the can contents. The possible extent of the variability that may be encountered in a single can is illustrated in Table III, where separate determinations were made on the poorer

TABLE III—VARIABILITY OF THE COLOR IN SINGLE CANS OF TOMATOES (COMPARISONS OF THE COLOR VALUES OF THE BETTER TWO-THIRDS WITH THE POORER ONE-THIRD)

Treatment	Per Cent Transmittance at 485 mμ	
	Better Two Thirds	Poorer One Third
Selected good color	42	43
Mixture	40	64
Selected poor color	53	63
Selected good color	32	35
Mixture	35	58
Selected poor color	61	61
Selected good color	30	33
Mixture	31	44
Selected poor color	47	48
Selected good color	25	34
Mixture	31	42
Selected poor color	49	49
Selected good color	24	26
Mixture	32	51
Selected poor color	46	51
Selected good color	38	46
Mixture	44	50
Selected poor color	61	59
Selected good color	39	44
Mixture	33	49
Selected poor color	49	49

third and the better two-thirds of each can. With one exception, samples which consisted of tomatoes selected for uniformly poor or for uniformly good color did not vary by more than 5 per cent transmittance between the better two-thirds and the poorer third, while those cans which were prepared from a mixture of material with no attempt made at selecting uniformly colored fruit, varied frequently by as much as 20 per cent between the two fractions.

This problem of variability within the can applies only to the whole tomatoes and not to the comminuted products. In the practical grading of canned tomatoes, it may be necessary to include the effect of variability by making a color determination on the poorer fraction only. Whether this fraction should be one-half or one-third, or a still smaller portion remains to be determined. In this connection it is interesting to note that the standard of quality for canned tomatoes under the

Food, Drug, and Cosmetic Act includes a minimum color requirement based on the poorer colored half of the drained tomatoes (1).

Variability among cans is also to be considered. Data in Table IV show the color determinations on 12 successive cans of two commercially prepared samples of canned tomatoes. On the average the two samples are rather close together in color rating, but there is a marked difference in the color of the last can of each sample compared with the first can of each sample.

TABLE IV—Variability in Color of Individual Cans in Two Case Lots of Commercially Prepared Canned Samples (Arranged in Order of Decreasing Color Intensity)

	Per Cent Transmittance at 485 mμ	
	Sample A	Sample B
	28	25
	30	28
	32	30
	34	31
	35	31
	37	32
	37	34
	38	34
	40	34
	40	35
	41	41
	50	46
Average	36.8	33.4
Standard Errors of the Standard Deviations:		
for 2 cans	5.50	5.25
4 cans	3.14	3.11
6 cans	2.20	2.14
8 cans	1.70	1.63
10 cans	1.36	1.32
12 cans	1.14	1.10

The standard errors of the standard deviations shown in Table IV indicate, on the basis of the data obtained, how closely the values obtained by averaging a given number of samples may be expected to approach the true average for that sample. The values selected for the standard error determination for two cans were in each case the two extremes, those selected for the standard error determination for four cans were the two highest and the two lowest, and so on. In this way the largest possible standard errors were obtained. The data indicate that as many as eight individual cans need to be averaged before the mean value could be expected to approach within 2 per cent, the true average for the lot.

Some Correlations:—Correlations between organoleptic ratings and objective values for large numbers of commercial samples obtained from packs processed during three different years, resulted in "r" values between .76 and .87. In one case, where the samples were prearranged in order of increasing transmittance values, there was no general agreement among the judges that the samples required any rearrangement, although several samples could have been interchanged with no objection from the judges. Since correlations between groups of judges rarely exceeded .85, it was concluded that there was satis-

factory agreement between organoleptic ratings and the transmittance values.

The data in Table V show the relation of selected raw tomatoes to color measurements. Each series of samples was prepared by carefully selecting tomatoes of like ripeness, and canning them as a separate sample. In general, those samples selected as riper on the basis of the appearance of the raw product, gave lower readings both by the objective and the organoleptic test. The correlation coefficient of .78 between the objective and the organoleptic test was not as high as might be hoped. This relatively low correlation may be due to the large size of the tomato unit, which made it practically impossible to have each can the same as every other can in the same sample.

TABLE V—Relation of Selection of Raw Tomatoes to Color Measurements of Canned Tomatoes

Treatment	Objective Per Cent Transmittance at 485 mμ	Organoleptic (1 = Best Color) (10 = Poorest Color)*
	Series A	
Ripest	58	4.4
Riper	59	6.5
Greener	67	8.3
Greenest	77	9.8
Field run	72	5.4
	Series B	
Ripest	38	1.1
Riper	47	2.6
Greener	58	1.9
Greenest	61	4.5
	Series C	
Riper	49	2.0
Medium	60	2.2
Greener	63	3.1
Factory run (Fancy)	57	3.2
	Series D	
Ripest	44	1.7
Riper	47	2.0
Medium	45	2.0
Greener	47	3.2
Greenest	57	2.8
	Series E	
Riper	36	1.4
Medium	52	3.8
Greener	56	4.2

Correlation coefficient .78.

Correlations between objective and organoleptic tests for tomato juice show a correlation coefficient of .91, as shown in Table VI. In the case of tomato juice, where the entire sample is first thoroughly mixed, the similarity between duplicate cans of the same sample may be expected to be much better than that between duplicate cans of whole tomatoes.

Data in Table VI also indicate that there is very little difference in the color rating of juice, before canning, immediately after canning, and canned juice stored for 2 months at room temperature. The data also indicate that tomatoes that have been harvested before color was

TABLE VI—EFFECT OF STAGE OF RIPENESS, HOLDING AND PROCESSING OF RAW TOMATOES (RUTGERS) ON THE COLOR MEASUREMENTS OF THE RAW AND CANNED JUICE

State of Ripeness	Holding Period (Hours)	Raw Juice	Canned Juice		Organoleptic (1 = Best 10 = Poorest)
			Per Cent Transmittance 1 Day After Canning	60 Days After Canning at 485 mμ	
			Series A		
Ripest	4	68	66	67	1.0
Medium	4	74	72	72	2.1
Medium	52	72	69	70	1.3
Medium	100	65	64	63	2.3
Greener	4	80	79	79	4.0
Greener	52	79	78	78	4.9
Greener	100	70	66	68	3.6
Greener	172	61	56	60	1.1
			Series B		
Medium	4	74	77	73	2.9
Pink Stage	4	84	84	83	8.7
Riper of above	32	82	81	80	8.4
Riper of above	56	75	70	73	4.9
Riper of above	80	67	68	65	1.0
Medium selected	32	83	81	81	8.0
Medium selected	56	77	73	74	7.0
Medium selected	80	68	69	67	2.4
Greener selected	32	86	85	84	9.7
Greener selected	56	75	73	76	5.9
Greener selected	80	73	74	77	4.3
			Series C—Glowers Globe (Pink Variety)		
Riper	4	67	66	66	1.1
Medium	4	77	77	76	6.3

Correlation coefficient .91.

well developed show a continuous improvement in color upon holding at room temperatures for periods up to 7 days.

Objective and organoleptic color ratings for several varieties of tomatoes are given in Table VII. For these samples, no effort was made to select tomatoes of uniform ripeness; hence, the correlation for the whole tomatoes is only .25, while the correlation for the juice of

TABLE VII—COLOR MEASUREMENTS OF SOME TOMATO VARIETIES

Variety	Tomato Juice		Tomatoes	
	Objective*	Organoleptic†	Objective*	Organoleptic†
Marglobe	58	1.8	57	2.8
46–CS22	59	2.8	46	4.8
Early Belle	61	2.8	57	5.3
Earliana	63	2.8	53	3.0
Fordhook Hybrid	64	3.2	46	2.8
Keystone	66	2.0	46	2.1
Clinton Hybrid	66	3.5	42	2.1
Glowers Globe	69	3.0	42	3.5
Valiant	69	4.6	48	3.3
Golden Jubilee	85	—	85	—
Correlation coefficient	.85		.25	

*Per cent transmittance at 485 mμ.
†1 = best color; 10 = poorest color.

the same varieties was .85. The Golden Jubilee variety was of course extremely poor in red pigment content, and was not included in the correlations.

Summary

A method is presented for determining objectively the color of raw and processed tomatoes and tomato products. The color of a blended sample is extracted with benzol, diluted and centrifuged, and measured photometrically for per cent transmittance. The method applies to red and pink tomatoes, but needs to be modified for yellow-orange tomatoes. Simple filter colorimeters may be used as well as more sensitive spectrophotometers. Sampling procedure is important, and for canned tomatoes variability within the can is important and may be evaluated by measuring separately different fractions of the can contents. A minimum of eight cans selected at random from a lot should be used for sampling a lot of canned tomatoes. The objective test showed a high correlation with organoleptic ratings for juice samples, and somewhat lower correlations for whole tomatoes. This latter is probably due to the impossibility of preparing identical samples of canned tomatoes. There was good correlation between the selection of the raw tomatoes and the color tests on the canned product. Tomatoes which had not ripened fully at the time of harvest, showed improvement in red pigment content when held for periods up to 7 days at room temperatures.

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Yields of Three Industrial Varieties of Sweet Potatoes

By W. D. Kimbrough, *Louisiana Agricultural Experiment Station, Baton Rouge, La.*

THERE has been considerable interest in the production of sweet potatoes for industrial purposes during the last decade. The writer (3) and Anderson and others (1) have shown that with early planting and a long growing season high yields of sweet potatoes can be produced. Until recent years there was no interest in varieties of sweet potatoes especially adapted for industrial use. One of the objects of the sweet potato breeding program in Louisiana is to produce varieties especially suitable for this purpose. Selections have been made for high yield and high solid content which, in freshly dug potatoes, means high starch content. High solid content is usually associated with low carotene content and it now seems that carotene content may be an important factor when sweet potatoes are to be dehydrated for feed especially for dairy cattle. Two industrial varieties have been introduced. One is a Louisiana introduction L 4–5 named Pelican Processor. The other is a U. S. D. A. seedling B–196 named White Star. The Triumph variety has been considered the standard by which to judge other varieties or seedlings to be used for industrial purposes, although it has been grown for years as a table stock variety. None of these varieties has an appreciable carotene content.

The objects of this experiment were to compare the yields and starch contents of sweet potatoes of Triumph, Pelican Processor and White Star varieties when planted at two times and harvested at three dates. The plots were 40 feet long and 4 feet wide on Lintonia silt loam at the Experiment Station farm at Baton Rouge. There were five replications for each treatment. Plants were set 2 feet apart in the row. There was no injury to plants from cold prior to harvest. Starch[1] determination were made by the method described by Balch (2).

The results obtained are shown in Tables I and II. The marketable yields given for industrial use include the entire crop, except for very small stringy roots. The results show again that the earlier planted and later dug potatoes produced the largest yields. While all three varieties produced good yields the Pelican Processor generally yielded slightly more than the Triumph, and the White Star significantly outyielded the other two varieties by a considerable amount. Roots of White Star variety tended to be a little larger in size and somewhat rougher than those of the other varieties but were satisfactory for industrial use. Roots of the Pelican Processor variety were lower in moisture content, though it varied from 58.10 to 66.45 per cent, than those of the other two varieties. There was not a great deal of difference between the moisture content of roots of the Triumph variety and those of the White Star. Due to the higher starch content, Pelican Processor potatoes produced considerably more starch per acre than the Triumph. The starch content of White Star potatoes was not as high as that of

[1]Starch determinations were made at the U. S. Horticultural Field Station, Meridian, Mississippi.

TABLE I—YIELDS, MOISTURE AND STARCH CONTENTS, AND CALCULATED STARCH PER ACRE OF THREE VARIETIES OF SWEET POTATOES (THREE YEAR AVERAGE, 1943–1945)

Variety	Date of Planting	Date of Digging	Yield of Marketable Potatoes (Bu Per Acre)	Moisture (Per Cent)	Starch (Per Cent)	Starch (Pounds Per Acre)
Triumph..........	Apr	Sep	316.6	65.72	25.20	4771.0
Pelican Processor...	Apr	Sep	338.5	60.97	29.70	6050.6
White Star.........	Apr	Sep	432.2	64.10	26.76	7052.2
Triumph...........	May	Sep	245.6	65.49	25.35	3734.2
Pelican Processor...	May	Sep	230.2	61.02	29.39	3887.2
White Star.........	May	Sep	340.4	64.13	26.30	5368.8
Triumph	Apr	Oct	405.9	66.25	25.46	6206.6
Pelican Processor...	Apr	Oct	443.6	62.29	28.77	7629.7
White Star.........	Apr	Oct	600.0	65.71	26.04	9256.1
Triumph..........	May	Oct	293.3	66.52	24.62	4641.0
Pelican Processor...	May	Oct	349.5	62.73	28.49*	5965.3
White Star........	May	Oct	451.7	65.39	26.51	7197.6
Triumph..........	Apr	Nov	455.1	66.10	25.60	7010.0
Pelican Processor...	Apr	Nov	517.6	64.23	27.38	8490.7
White Star........	Apr	Nov	710.4	67.77	24.15	10260.3
Triumph..........	May	Nov	343.7	67.46	24.33	5029.4
Pelican Processor...	May	Nov	392.8	64.75	27.15	6434.1
White Star.........	May	Nov	597.8	67.29	24.81	8850.9

*1944 starch percentage calculated from moisture.

TABLE II—MEAN YIELDS OF DATA PRESENTED IN TABLE I*

Variety	Mean Yield (Bu Per Acre)	Year	Mean Yield (Bu Per Acre)	Time of Planting	Mean Yield (Bu Per Acre)	Time of Harvest	Mean Yield (Bu Per Acre)
Triumph..........	344	1943	449	Apr	480	Sep	318
Pelican Processor..	379	1944	415	May	361	Oct	425
White Star........	523	1945	382	—	—	Nov	503

Differences required for significance at 1 per cent level:
Between varieties, years and times of harvest—26.4 bushels
Between time of planting—21.5 bushels
*Calculations made by J. B. Edmond.

Pelican Processor, but the yields were so much greater that more starch was produced per acre.

The results show that both Pelican Processor and White Star varieties are superior to Triumph so far as production for industrial use is concerned. Under the conditions of this experiment White Star was much better than Pelican Processor. The data again show that it is possible to obtain yields of sweet potatoes so large that it should make possible their production for industrial use. So far, however, industrial ventures have not been very successful. These have been largely confined to the production of starch from sweet potatoes. Excellent starch has been produced but the yield of roots at a low enough cost and in the quantities desired has not been satisfactory. The dehydration of sweet potatoes as a carbohydrate feed for live stock is being done successfully in connection with the production of fresh market sweet potatoes. Feeding experiments have shown that good dehydrated sweet potato meal has a feeding value approximately 90 per cent of

that of shelled corn. However, the feed problem will not be materially helped by sweet potato meal as long as it is produced as a by-product. That dehydrated sweet potatoes can be successfully used for the manufacture of alcohol has been demonstrated. The main bottle neck hindering the industrial production of sweet potatoes at present seems to be the production of sufficient early plants at low cost, for plants must be set to the field early if high yields are to be expected. Mechanization to reduce the per acre cost of harvested sweet potatoes is also essential to their production for industrial use.

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Loss of Carotene in Preserved Samples of Sweetpotatoes[1]

By W. S. Anderson, *Mississippi State College, State College, Miss.*

In connection with the testing of many varieties and seedling selections of sweetpotatoes at this Station, it has been desirable to determine the carotene content at harvest of hundreds of samples. Harvesting must be accomplished within a period of a few weeks, and for any one test the actual harvest seldom extends over a period longer than 1 or 2 days. This makes it necessary to preserve samples of the roots for future determination of the various constituents.

In the fall of 1945 for the purpose of finding out whether significant loss of carotene occurs in alcohol-preserved samples when stored in the laboratory, the test described below was carried out.

On October 8, twenty-six 5-gram aliquots of rasped Unit I Porto Rico samples were preserved as follows:

Roots were washed, dried, sliced into two pieces lengthwise and run through the rasp sampling machine. The material thus ground was collected in a pint fruit jar. Five-gram samples were immediately weighed for preservation.

The samples were washed into 2-ounce screw-cap bottles with ethyl alcohol which had been re-distilled over KOH, filling the bottles practically full. The preserved samples were placed promptly in corrugated cardboard boxes, and stored on the floor of the laboratory. This meant that the samples were stored in the dark at room temperature.

Because the sampling was done at a field station it was not possible to make a carotene determination on the day of harvest. Beginning on October 22 determination of the carotene in two of these samples was made every 7 days until December 17. Thereafter 2 weeks elapsed between sample analyses. The method used in these determinations was essentially that described by Moore (1). The results are shown in Table I.

TABLE I—Carotene of Unit I Porto Rico Sweetpotatoes After Preservation for Different Periods of Time

Days Preserved	Gammas Carotene Per Gram (Fresh Basis)	
	Bottle 1	Bottle 2
14	42.25	40.95
7	36.21	36.21
7	35.66	35.10
7	30.71	31.20
7	32.18	33.15
7	34.16	34.12
7	32.18	32.66
7	33.15	32.18
7	32.66	33.15
17	27.63	27.63
14	26.00	26.00
15	22.10	22.49
13	19.50	19.50

[1]Contribution from the Mississippi Agricultural Experiment Station, published with the approval of the Director as Journal Article 159 (New Series).

The author gratefully acknowledges the assistance of Marvin Gieger, Chemist, Mississippi Agricultural Experiment Station, and Elsie Gilliland, Minor Scientific Aide, U. S. Department of Agriculture, who made the carotene determinations.

These data show that it is unwise to keep samples of sweetpotato under ordinary laboratory storage conditions for long periods of time if carotene determinations are to be of value. Fifteen per cent of the carotene had been lost in the first 4 weeks. How much of this loss occurred between the time of preservation and the time of the first determination after 14 days storage, of course, is not known. In handling large numbers of samples it is always necessary that some time elapse between preservation and analysis. In another month the loss had increased to 25 per cent, in 3 months it was 35 per cent and in 4½ months (on February 15) it had reached a total of 52 per cent.

Because of the results obtained in these tests, it has since been the custom at this station to try to complete all carotene determinations within 2 weeks after harvesting and preserving the samples. These observations suggest the need for a more extensive study of practicable procedures for holding large numbers of sweetpotato samples for later carotene determination.

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Yields of Porto Rico Sweetpotatoes in Relation to Size of Plants Set (A Preliminary Report)

By ARTHUR MEYER and JOHN C. CLARK, *University of Tennessee, Knoxville, Tenn.*

THE Porto Rico variety of sweetpotato has the reputation of producing objectionable quantities of roots that are too large to be admitted to the better market grades. Farmers generally complain also about the low yields of this variety. They have been slow to change to Porto Rico because of these two factors.

A report reached the University of a gardener who was getting high-quality Porto Ricos by placing long cuttings in the row instead of setting plants. Trials were made in experimental plots with results indicating that the customary methods of handling this crop are faulty.

METHODS

Unit No. 1 Porto Rico was the variety used in the trials herein reported. In 1946, plots consisting of four replications each were set in five different locations in the state. In 1947, the same plan was followed, and records were obtained from four locations.

The trials consisted of three treatments: short plants with only two nodes set in the ground, longer plants with four nodes set in the ground, and still longer plants with six nodes set. All plants were produced by the usual methods.

Spacing was 3½ feet between rows, and 1 foot between plants in the row. Fertilizer applications, cultivation, and method of digging were variable, conforming to the practices followed on the farms where the plots were located. The potatoes were rigidly graded in the field, by U. S. standards.

RESULTS

The yields are recorded in Table I, in terms of U. S. No. 1 grade. Roots not making this grade are not reported, because they have little market value.

The figures have not been analyzed, but are presented here as a preliminary report. Along with observations made in the field, these figures seem to indicate that growers may obtain higher yields of the better grades of Porto Rico sweetpotatoes by setting more nodes of the plant in the ground.

The vine growth of the Unit No. 1 Porto Rico is rank, with the nodes relatively far apart. The plants, or slips, produced in the hotbed have a tendency to be of the same nature. Consequently, to have plants with sufficient nodes to be placed in the ground, and yet not have the plants too cumbersome for field setting, the grower probably should bed his potatoes earlier, by a week or 10 days, and operate the hotbed at a lower temperature than is ordinarily done; 75 degrees F has given satisfactory results. In these trials, at this temperature, the internode length of the Porto Rico plants has been about equal to that for the Nancy Hall at 85 degrees F.

TABLE I—YIELDS OF U. S. NO. 1 PORTO RICO SWEETPOTATOES IN 1946 AND 1947

Location	Treatment	1946		1947		Yield 2-Year Average
		Days in Field	Yield Per Acre	Days in Field	Yield Per Acre	
Knox County	2 nodes	162	306.0	136	236.7	271.35
	4 nodes		417.5		282.6	349.85
	6 nodes		445.9		237.4	341.65
Crockett County	2 nodes	122	194.4	113	146.9	170.65
	4 nodes		233.2		149.5	191.35
	6 nodes		266.1		198.9	228.00
Gibson County	2 nodes	158	237.6	178	165.4	201.50
	4 nodes		262.6		142.3	202.45
	6 nodes		279.1		179.0	229.05
Weakley County	2 nodes	160	122.2	—	—	—
	4 nodes		164.7	—	—	—
	6 nodes		181.3	—	—	—
Henry County	2 nodes	147	156.3	135	127.6	141.95
	4 nodes		171.9		157.3	164.60
	6 nodes		199.6		142.5	171.05
Mean, all locations	2 nodes					181.53
	4 nodes					214.59
	6 nodes					230.51

The variation in plot yields in 1947 indicates that some undetermined factor or factors may affect the formation of potatoes in the Porto Rico variety. A detailed study of these has been planned.

SUMMARY

The evidence to date gives the following indications:

1. Within the limits of the number of nodes used, the Porto Rico sweetpotato yields U. S. No. 1 potatoes in relation to the number of nodes set in the ground.
2. A hotbed temperature of 75 degrees F may be more desirable for plant production than higher temperatures.
3. Undetermined factors probably influence the formation of potatoes in the Porto Rico variety.
4. The fact that these possibilities have been overlooked in the past may impair the value of the previous yield records on Porto Rico.

Effects of Spraying a Sprout Inhibitor on Potato Plants in the Field[1]

By J. HOWARD ELLISON and ORA SMITH, *Cornell University, Ithaca, N. Y.*

SERIOUS losses result each year from the sprouting of potato tubers in storage. Marked reduction in sprout growth has been attained by the application of the methyl ester of alpha naphthaleneacetic acid (MENA) to potatoes as they were placed in storage.

This study was undertaken to determine some effects of applying the sprout inhibitor to the plants in the field rather than directly to the tubers. It was hoped that translocation of the chemical from the leaves to the tubers would reduce the sprout growth in subsequent storage. An advantage of the field application would be the possibility of mixing the inhibitor with one or more of the grower's regular fungicidal or insecticidal sprays, eliminating the extra trouble of treating the tubers later as they were placed in storage.

MATERIAL AND METHODS

To determine whether yield or quality of the crop was affected by the application of MENA to the plants, a factorial experiment was designed in 1946 in a field of potatoes of the Houma variety, growing on a Lordstown gravelly silt loam soil. The experimental plots received excellent commercial care.

Each plot consisted of 25 feet of row with a guard row on either side. Treatments were randomized within each of three replications.

Treatments consisted of none, 3500 and 7000 ppm MENA in aqueous spray applied on the following dates: July 17 only (E), July 17 plus August 19 (EM), August 19 only (M), August 19 plus September 11 (ML), September 11 only (L), and July 17 plus August 19 plus September 11 (EML).

Sprays were applied at the rate of 300 gallons per acre through a knapsack-type sprayer.

Total yield and the yield of U. S. No. 1 size potatoes were obtained and expressed in bushels per acre. Specific gravity of the U. S. No. 1 size potatoes was taken as a measure of the starch content and mealiness of the tubers.

Samples of 24 tubers each were stored at 50 degrees F from November 20, 1946, to January 27, 1947, at which time sprouts were removed and weighed. A second set of samples was stored at 40 degrees F from November, 1946, to May, 1947, when samples were taken for carbohydrate determinations.

Tubers stored at each temperature were planted in June, 1947, to determine their value as a seed stock. The tubers stored at 50 degrees

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[1]Paper No. 294, Department of Vegetable Crops, Cornell University, Ithaca, N. Y.

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F had been desprouted once in January and again before planting. Very few sprouts appeared at 40 degrees F, but these also were removed before planting.

In this experiment yield was taken as an indication of the value of the "seed". Each plot consisted of 27.5 feet of row and treatments were randomized within each of four replications.

Results from the 1946 Experiment

There were no significant differences among the early application (E), the early plus midseason (EM) and the early plus midseason plus late (EML) applications in their various effects; nor did real differences occur between the midseason application (M) and the midseason plus late treatment (ML), so for simplicity of presentation, all of the above multiple applications, EM, ML and EML will be omitted from further discussion in this paper. Consideration will be confined to the three single application dates, namely early (E), midseason (M) and late (L).

TABLE I—Yield of U. S. No. 1 Size Potatoes in Bushels Per Acre (1946)*

Date of Application	Concentration of MENA in Aqueous Spray		
	3500 Ppm	7000 Ppm	Mean
Jul 17 (E)	200	155	178
Aug 19 (M)	299	270	284
Sep 11 (L)	329	326	328
Mean	276	250	Check = 309

*LSD for MENA versus check at .05 = 46; at .01 = 61.
LSD for dates of application at .05 = 93; at .01 = 106.

Table I shows that the check plots yielded significantly more than those sprayed with MENA at the early (E) date, but no statistically significant reduction in yield resulted from the MENA when sprays were applied at midseason (M) or late (L). The early application (E) severely injured the foliage, whereas the later treatments did not, thus explaining the difference in yield. There was no significance between 3500 ppm and 7000 ppm of MENA in the sprays.

The early treatment (E) caused a very serious "pitted scab-like" injury to the surface of the tubers, similar to that reported by Smith, Baeza and Ellison (2), but no defects were associated with the midseason (M) and late (L) treatments.

TABLE II—Specific Gravity of Tubers*

Date of Application	Concentration of MENA in Aqueous Spray		
	3500 Ppm	7000 Ppm	Mean
Jul 17 (E)	1.066	1.057	1.062
Aug 19 (M)	1.079	1.080	1.080
Sep 11 (L)	1.083	1.083	1.083
Mean	1.076	1.073	Check = 1.084

*LSD for MENA versus check at .05 = .025; at .01 = .034.
LSD for dates of application at .05 = .031; at .01 = .041.

Results concerning the specific gravity of tubers are presented in Table II. Although no significant difference was found in the main effect of either MENA versus the check, or of dates of application, still there is a significant interaction between the two, showing that MENA lowered the specific gravity more at the early (E) date than at either the midseason (M) or the late (L) date.

An examination of Table III shows that the most effective sprout inhibition was associated with the early treatment (E), but that the midseason application (M) reduced sprouting significantly compared to the check. There was no significant difference between the late date (L) and the check, nor between 3500 ppm and 7000 ppm MENA.

TABLE III—WEIGHT OF SPROUTS IN GRAMS PER 24 TUBERS STORED AT 50 DEGREES F FROM NOVEMBER 20, 1946 TO JANUARY 27, 1947*

Date of Application	Concentration of MENA in Aqueous Spray		
	3500 Ppm	7000 Ppm	Mean
Jul 17 (E)	15.0	8.3	11.6
Aug 19 (M)	20.3	25.0	22.6
Sep 11 (L)	41.7	40.7	41.2
Mean	25.7	24.7	Check = 42.1

*LSD for MENA versus check at .05 = 11.1; at .01 = 14.9.
LSD for dates of application at .05 = 19.3; at .01 = 25.9.

Respiration rates of tubers, as measured by the evolution of CO_2, were determined for certain treatments both before and after sprouting occurred. No differences were found before sprouts appeared, but after sprouting began the tubers receiving the midseason treatment respired significantly less than the check, but there was no significant difference between the late treatment and the check.

Results similar to those above were found concerning the reducing sugar content of tubers; namely, treated tubers contained significantly less reducing sugar than untreated ones, and in general the earlier the treatment the lower the reducing sugar content. These results may have a practical significance since, as Denny and Thornton (1) have pointed out, relatively low reducing sugar content makes for attractive, light colored potato chips, whereas high reducing sugar content produces undesirable, dark colored chips.

SEED VALUE OF TUBERS FROM PLANTS SPRAYED IN THE FIELD WITH MENA

Table IV indicates no significant difference between treated and untreated tubers concerning their value as seed stock, when planted the following year. The only significant difference resulting from planting tubers from the 1946 experiment was that seed stored at 50 degrees F produced lower yields than did seed stored at 40 degrees F. This is probably due to the fact that the tubers at 50 degrees F were desprouted twice, whereas those at 40 degrees F required practically no desprouting.

TABLE IV—1947 YIELD OF U. S. NO. 1 SIZE POTATOES IN BUSHELS PER ACRE USING TUBERS FROM THE 1946 EXPERIMENT AS SEED STOCK*

Date of Application	Concentration of MENA in Aqueous Spray						
	Check		3500 Ppm		7000 Ppm		
	Temperature at Which Seed Stock Was Stored (Degrees F)						
	40	50	40	50	40	50	Mean
Jul 17	407	353	453	378	396	318	384
Aug 19	437	385	423	420	422	386	412
Sep 11	431	374	416	377	420	361	396
Concentration mean	398		411		384		

*Temperature means: 40 degrees F = 423; 50 degrees F = 373.
LSD for temperature at .05 = 21; at .01 = 27.
No significant difference for MENA versus check.
No significant difference for dates of application.

SUMMARY AND CONCLUSIONS

In 1946 the methyl ester of alpha naphthaleneacetic acid (MENA) was sprayed on potato plants in the field to determine whether the tubers would exhibit sprout inhibition in subsequent storage compared to the checks.

MENA at 3500 and 7000 ppm was applied on each of three dates: July 17, August 19 and September 11. Checks were included and three replications were used.

The July application reduced both yield and specific gravity of the tubers, but no bad effects were associated with the August or the September treatment.

Sprouting in storage was best controlled by the July application, but the August spray reduced sprouting significantly compared to the check. No inhibition was associated with the September application.

Respiration rates of treated versus check tubers were not significantly different before sprouts appeared, but treated tubers respired significantly less after sprouts developed.

MENA treated tubers contained significantly less reducing sugar than did the checks.

Tubers from the 1946 experiment were planted in 1947 to determine their value as seed. No significant difference was found between yields from treated and check tubers.

MENA was as effective at 3500 ppm, as it was at 7000 ppm throughout the experiment, suggesting that a still lower concentration might prove satisfactory, especially early in the season when the plants are susceptible to MENA injury. The study is being continued with emphasis being placed on lower concentrations.

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Killing Potato Vines[1]

By FRED MCGOLDRICK and ORA SMITH, *Cornell University, Ithaca, N. Y.*

THE purpose of these investigations was (a) to determine the effect of controlled death of vines on yield, (b) to determine the effect of certain of these agents on quality as applying to specific gravity, surface condition, and internal appearance, (c) to compare some of the killing materials now being used, and others which appear to have potentialities, and determine the efficiency with which they accomplish the results desired, and (d) to ascertain whether the stage of maturity of potato plants at the time of kill affects the response to given killing agents.

PROCEDURE

In 1946 a factorial experiment involving killing agents and dates of kill was conducted on upland soil with the variety Chippewa. In 1947 a similar experiment was carried out in the same general location using the variety Sebago. An additional randomized block experiment was conducted in 1947 using 10 killing treatments and three replications. Plot size in all experiments was 25 feet of row with a short untreated alleyway between ends of plots. Single guard rows separated all plots. All spraying applications were made with hand spraying equipment; frequent shaking of the spray tank being used as a means of agitation. All sprays were applied at the rate of 125 gallons per acre. Harvests were made 10 days after the killing sprays were applied in the 1946 experiment and 14 days afterward in the 1947 factorial experiment. In the 1947 random block experiment all plots were harvested 18 days after killing treatments were applied. The tubers were stored in cloth bags for approximately 2 weeks after harvesting before weighing and grading. Specific gravity determinations were made shortly after grading and tuber samples were taken for storage and further study.

RESULTS

Yield:—As can be seen in Table I, yield was reduced by destruction of vines prior to natural maturity and death in 1946. Considering the average of all killing dates the control allowed to reach natural maturity was significantly higher in yield than any other killing treatment or control. In general, those treatments which killed most rapidly gave lowest yields, indicating that daily increase in tuber size was considerable during the intervals between each spray application and harvest. No significant difference occurred between the unsprayed control harvested simultaneously with the sprayed plots and those treatments which resulted in a poor kill of vines. The date of the first killing frost was considerably later than usual in this area and the naturally maturing control had an unusually long growing period. No grower would assume the risk of delaying harvest to a comparable date. A very highly

[1]Paper No. 296. Department of Vegetable Crops, Cornell University, Ithaca N. Y.

significant difference was found between the first and second dates of kill with the difference between the second and third being only slightly significant.

TABLE I—EFFECT OF VINE KILLING ON YIELDS AND VASCULAR DISCOLORATION (CHIPPEWA — PLANTED MAY 22, 1946)

Treatments*	Average Yield U .S. No. 1 (Bu Per Acre)				Per Cent Vascular Browning (Based on 10-Tuber Samples)			
	Date of Application			Means Treatments	Date of Application			Means Treatments
	Aug 12	Aug 24	Sep 5		Aug 12	Aug 24	Sep 5	
1 Control 1	187	297	357	280	7.5	7.5	7.5	7.5
2 Control 2	260	314	368	314	7.5	0.0	2.5	3.3
3 Dow 66 Improved	199	368	304	291	7.5	20.0	72.5	33.3
4 Sinox General	203	330	336	290	10.0	12.5	52.5	25.0
5 2-4D + Diesel Oil	218	377	395	330	5.0	7.5	47.5	20.0
6 2-4D	279	348	403	344	15.0	7.5	7.5	10.0
7 MENA	248	404	417	356	17.5	5.0	7.5	10.0
8 Sizz Flame	229	328	378	312	5.0	12.5	57.5	25.0
9 Esso HC9	243	296	390	310	7.5	5.0	12.5	8.3
10 $NaNO_2$	235	379	370	328	15.0	20.0	45.0	26.7
11 Control 3	411	409	414	411	0.0	2.5	7.5	3.3
Mean killing dates	247	350	376		8.9	9.1	29.1	
	L.D.S. between killing agents = 62 (odds 99:1) L.D.S. between killing dates = 33 (odds 99:1)				L.D.S. between killing agents = 13.8 (odds 99:1) L.D.S. between killing dates = 7.2 (odds 99:1)			

*1, Harvested on day killing sprays applied; 2, harvested on same day as killed plots; 3, 2½ gallons Dowspray 66 Improved per acre; 4, 1¼ quarts Sinox General plus 2½ gallons diesel oil per acre; 5, 6¼ pounds 2-4D, in 118 gallons diesel oil plus 6 gallons Triton B1956 per acre; 6, 6¼ pounds 2-4D per acre; 7, 2½ gallons 90 per cent methyl ester of naphthaleneacetic acid per acre; 8, approximately 3 minutes per plot with a Hauck hand burner; 9, 6¼ gallons Esso HC-9 per acre; 10, 125 pounds sodium nitrite per acre; and 11, harvested after natural maturity of the vines (October 4). All chemicals were applied in water with the exception of the 2-4,D in oil treatment (No. 5).

TABLE II—EFFECT OF VINE KILLING ON YIELDS AND VASCULAR DISCOLORATION (SEBAGO — PLANTED MAY 26, 1947)

Treatment*	Average Yield U. S. No. 1 (Bu Per Acre)			Per Cent Vascular Browning (Based on 20 Tuber Samples)		
	Dates of Application		Means Treatments	Dates of Application		Means Treatments
	Aug 27	Sep 10		Aug 27	Sep 10	
1 Control 1	264	381	323	10.0	20.0	15.0
2 Control 2	354	497	425	6.0	30.0	18.0
3 Dow 66 Improved	317	394	355	68.5	73.5	71.0
4 Sinox General	327	394	360	35.0	66.0	52.0
5 Cyanamid X-5	318	414	366	35.0	55.0	43.5
6 Cyanamid X-1	293	410	352	37.5	65.0	51.0
7 Penite 6	313	344	328	48.5	76.0	62.5
8 Sizz Flame	271	400	335	61.0	77.5	69.5
9 2-4-5 Trichlorophenoxyacetic acid	391	391	391	55.0	35.0	45.0
10 2-4D	289	432	360	35.0	50.0	42.5
11 Control 3	491	545	518	12.5	21.0	17.0
Mean killing dates	330	418		39.5	45.5	
	L.D.S. between killing agents = 84.5 (odds 99:1)			L.D.S. between killing agents = 26.4 (odds 99:1)		
	L.D.S. between killing dates = 36.0 (odds 99:1)			L.D.S. between killing dates = 11.0 (odds 99:1)		

*1, Vines pulled on day killing agents applied and tubers harvested on same day as killed plots; 2, 4, 8 and 11 treated as stated in Table I; 3, 2½ gallons Dowspray 66 Improved plus 2½ pounds aluminum sulphate per acre; 5, 50 pounds Cyanamid X-5 per acre; 6, 50 pounds X-1 per acre; 7, 1½ gallons Penite 6 per acre; 9, 25 pounds of sodium salt of 2-4-5 trichlorophenoxyacetic acid per acre; 10, 25 pounds 2-4D per acre.

TABLE III—EFFECT OF VINE KILLING ON YIELDS AND VASCULAR BROWNING (KATAHDIN — PLANTED JUNE 11, 1947)

Treatments*	Average Yield U. S. No. 1 (Bu Per Acre)	Per Cent Vascular Browning (Based on 20 Tuber Samples)
1 Control 1	325	15.0
2 Control 2	448	25.0
3 Dow 66 Improved	357	41.5
4 Sinox General	348	48.5
5 X-5	295	51.5
6 X-1	301	46.5
7 Penite 6	340	51.5
8 Flame	389	48.5
9 2-4-5 T	448	28.5
10 Penite 6 + Activator	354	60.0
	L.D.S. between treatments = 83.2 (odds 19:1)	L.D.S. between treatments = 21.6 (odds 19:1)

*1, 2, 3, 4, 5, 6, 7, 8, and 9 same as stated in Table II; 10, 1½ gallons Penite 6 plus 6½ pounds of activating compound per acre.

The results in Tables II and III indicate the same trends as found in 1946. The greater interval between spray application and harvesting tended to accentuate the difference between killing dates as compared to the second and third kills of 1946.

No significant interaction was found between killing agents and dates of kill.

Vascular Browning:—Discoloration in the vascular region as an apparent result of induced injury and death of potato vines has been reported. Counts were made on 10 tuber samples taken from stored lots of the 1946 experiment. Twenty tuber samples from each treatment were examined in 1947. The basal end of each tuber was pared down to expose the vascular region and one slice was made from apical to basal end to present a cut surface at the approximate center. Any obvious browning or darkening of the vascular region as far as ½ inch from the point of stolon attachment was considered a positive count. No attempt was made to distinguish accurately between degrees of discoloration. The data in Tables I, II and III indicate that all treatments which killed efficiently resulted in significant increases in vascular browning over that found in the unsprayed controls. The spraying treatments which gave partial kills only also resulted in increased vascular discoloration. High concentrations of methyl ester of naphthaleneacetic acid and 2,4–D also gave increased counts, although killing injury was very slight.

Apparently any treatment which extensively destroys leaf and stem tissues has a positive effect on browning in the vascular region of tubers. In 1946 counts were significantly higher in the third date of kill than in the first or second. No significant difference occurred between the first and second killing dates of 1947. A highly significant interaction was found between killing treatments and killing dates in 1946.

Efficiency of Kill:—Killing agents were compared in 1946 and estimations made on percentage of kill of leaves and stems. The results of these observations are shown in Table IV.

TABLE IV—EFFICIENCY OF KILL OF VINES

Treatments	1946—Per Cent Kill Based on Observations Made 10 Days After Application				1947—Per Cent (Dry Weight Basis) of Leaf and Stem Tissue Dead 6 Days After Application	
	Date of Application			Means Treatments	Treatments	Per Cent Dead Tissue
	Aug 12	Aug 24	Sep 5			
Dow 66 Improved	85	98	100	94	Control	11.8
Sinox General	80	90	100	90	Dow 66 Improved	80.2
2-4,D + Diesel Oil	60	50	95	68	Sinox General	73.7
2-4,D	5	5	45	18	Cyanamid X-5	69.3
MENA	10	10	40	20	Cyanamid X-1	64.6
Sizz Flame	80	90	95	88	Penite 6	78.7
Esso HC-9	15	15	35	22	Sizz Flame	76.6
$NaNO_3$	25	40	90	52	2-4-5 Trichlorophenoxyacetic Acid	23.1
					Penite 6 + Activator	90.6
					L.D.S. = 12.4 (odds 19:1)	

Six days after killing treatments were applied, three plants were selected at random in each plot of the random block experiment of 1947. These plants were clipped off at ground level and divided into (a) tissue considered dead, and (b) tissue appearing alive and succulent. Fresh and dry weight determinations were made on each lot. The mean percentages of dead tissue on a dry weight basis are presented in Table IV. The unsprayed controls had some dead basal leaves which accounts for the value presented. These plants showed no unusual injury and did not appear decidedly senescent. Penite 6 plus activator gave a significantly more complete kill than any other treatment. Dowspray 66 Improved was next most efficient, followed by Penite 6 without activator and sizz flame in that order. Cyanamid X–5 gave a slightly more efficient kill than Cyanamid X–1. 2–4–5 trichlorophenoxyacetic acid gave no apparent contact injury but at the end of 6 days a few lower leaves were turning yellow and dying.

Other Results:—Specific gravity determinations were made on samples from all plots and the data analyzed statistically. In general, those killing agents which destroyed top growth most efficiently and rapidly, reduced specific gravity as compared to poorer kills and controls. Highly significant differences were found between killing dates in 1946, with the naturally maturing control giving higher readings than any other samples.

Sprouting and shrinkage, other than sprouting, data taken during storage indicated no significant differences between killing agents but increased sprouting and shrinkage in the earlier harvested lots.

Tubers from the 1946 experiment were stored at 40 degrees and planted as cut seed in 1947. No significant effect of killing agents or killing dates was found in growth and yield of these plants.

Observations indicated that the more rapid killing treatments resulted in tubers which did not skin or scuff as badly as those from poorly killed plots.

SUMMARY AND CONCLUSIONS

The killing of potato vines has become a desirable or necessary practice with many growers and the question of when and how to destroy

top growth is a pertinent one. Field experiments were conducted in 1946 and 1947 in an attempt to gain additional information on this problem.

With the procedure followed, Penite 6 plus activator resulted in the most efficient kill observed. Dowspray 66 Improved, Penite 6 without activator, sizz flame, and Sinox General gave satisfactory kills. Cyanamid X–5 and X–1 gave fairly satisfactory kills, especially of leaves.

Yields were lower in rapidly killed plots than in controls or poorly killed plots. Differences between killing dates indicate that increase in tuber size during late stages of maturity warrant delaying the application of vine killers as long as possible unless greater size is objectionable.

Discoloration of the vascular region was decidedly increased by killing injury to top growth.

Specific gravity readings were lower in vine killed plots than in controls with the most rapidly killed plots giving lowest readings.

Sprouting and shrinkage loss other than sprouting was not significantly affected by killing agents. Early kill resulted in significantly greater loss than later kill.

Neither killing agents employed nor killing dates appeared to have a significant effect on the value of tubers as a source of seed.

A Study of Certain Factors Affecting "Buttoning" of Cauliflower[1]

By JOHN CAREW and H. C. THOMPSON, *Cornell University, Ithaca, N. Y.*

IN the production of the early or spring crop of cauliflower, considerable loss occasionally results from the occurrence of buttoned, or what frequently has been termed "prematurely-headed" plants. These plants are characterized by small exposed heads appearing shortly after field setting, at a time when normal plants of the same age appear to consist entirely of vegetative growth. A typical button is shown in Fig. 1. The term "button" probably originated from the resemblance of this small head to an ordinary white clothing button. Buttoned plants are invariably of no market value and in years when the condition is severe, the percentage of worthless plants results in considerable economic loss. Other terms used by growers in describing this abnormality are "premature-heading" and "bolting". In New York State, buttoning losses are usually confined to the early planted crop and are more severe in cold wet seasons.

FIG. 1. "Buttoned" cauliflower plant.

REVIEW OF LITERATURE

References to the problem of buttoning or "premature-heading" of cauliflower in plant science literature consist almost exclusively of statements based on observations rather than on research. Bailey (1), Bouquet (2), Brill (3), Enzie (4) and Garcia and Rigney (5) attributed buttoning to checks in growth. Extremely low temperature while the plant is young may cause it to button according to Jones and Ernst (6) who agreed with Judson (7) that plants stunted by remaining in the seedbed too long head prematurely.

The only investigation devoted solely to the problem of premature heading was conducted by Robbins, Nightingale and Schermerhorn

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Part of a thesis submitted by the senior author to the Graduate School of Cornell University in partial fulfillment for the degree of Doctor of Philosophy.

(8). These investigators were able to induce buttoning of cauliflower grown in sand, by limiting the nitrogenous salts in the nutrient solution. The authors suggested that insect, disease or mechanical injury to the roots or stems which seriously retards the absorption of nitrates would be expected to result in a premature head. Although mentioning no specific sources of information, Robbins, Nightingale and Schermerhorn make the statement that, "It is well known that cauliflower plants in the field may head prematurely if the plants obtain only a limited supply of nitrogenous salts".

Experiments and Results

The apparent parallel between the problem of buttoning of cauliflower and premature seeding or bolting of other vegetables such as beets, celery, cabbage, rutabagas, and onions determined the approach to the problem. In most instances commercial growing conditions were simulated as nearly as possible and efforts were directed toward ascertaining a practical solution to the growers' problem. Therefore head formation and not flower initiation was the measure of results in these investigations. Numerous experiments were conducted intermittently between 1941 and 1947, several of which are reported here.

Effect of Nitrogen Level and Low Temperature Exposure on Cauliflower Plants Grown in Two Different Nutrient Solutions:—Seed of the variety Improved Holland Erfurt was sown January 6, 1943. The seedlings were grown in composted soil until February 5 and then transplanted to white quartz sand in 8-inch asphalt-painted pots. Artificial illumination was supplied from 4 p m until 10 p m for the duration of the experiment. Following a 3-week period of complete nutrient solution culture, and a temperature of 60 to 70 degrees F, the various treatments of the following factorially designed experiment were initiated:

Nutrient Solution		*Nitrogen*		*Low Temperature*
1. Hoagland	x	1. Minus	x	1. 60 to 70 degrees F continuous
2. New Jersey		2. Complete		2. 40 to 50 degrees F for 2 weeks

With a small plant population, determining time of head formation was difficult. Previous experiments had indicated that a thick growing point while strong suggesting the presence of a small curd by no means could be used as a definite sign. It was finally decided to note the date of head exposure and at the same time observe the growth of the plant. This was done with the idea of comparing the time of actual curd formation as determined by feeling the growing point and by spreading the leaves as much as possible without permanently disturbing the vegetative growth. Table I indicates the length of time before the head became visible and plant growth at the time of harvest April 8. At this time the first buttoned plants had reached their maximum size before elongation of individual seedstalks.

Statistical analysis reflecting odds greater than 99 to 1 indicated that the nitrogen deficient solution reduced the number of days to head formation, the total top weight and the curd weight of the plants. Total top weight was somewhat greater using the Hoagland solution

TABLE I—EFFECT OF NUTRIENT SOLUTION, NITROGEN LEVEL AND TEMPERATURE ON THE GROWTH OF CAULIFLOWER

Treatment				Days to Head Appearance	Top Weight (Grams)	Curd Weight (Grams)
No.	Solution	Nitrogen	Temperature (Degrees F)			
1	Hoagland	Complete	60–70	38.9*	249.0**	17.6
2	Hoagland	Complete	40–50	38.9	176.8	8.6
3	Hoagland	Minus	60–70	36.1	57.0	3.0
4	Hoagland	Minus	40–50	33.4	50.9	3.0
5	New Jersey	Complete	60–70	40.0	254.5	12.1
6	New Jersey	Complete	40–50	38.0	91.2	5.1
7	New Jersey	Minus	60–70	30.8	40.2	3.3
8	New Jersey	Minus	40–50	34.0	37.8	1.9

*From February 26, date of initiation of nitrogen treatment (add 50 days for total age).
**Average of 5 plants.

and a continuous growing temperature of 60 to 70 degrees F. A low temperature period while reducing top growth did not result in a buttoned condition.

The plant response obtained coincides closely with that obtained by Robbins, Nightingale and Schermerhorn. As shown in Fig. 2, buttoning may be induced by insufficient nitrogen. Whether this is "premature-heading" in the same sense as applied to premature seeding of celery, beets and cabbage is doubtful in view of these data.

FIG. 2. Effect of nitrogen deficiency on occurrence of buttoning. Buttoned plant at left is deficient in nitrogen but the concealed head in the high nitrogen plant is just as large.

Effect of Crowding on the Occurrence of Buttoning:—Using the same variety, cauliflower seed was sown November 18, 1946. Two flats each containing 48 plants were grown under the following conditions: (a) crowded, that is, the plants were allowed to remain at a 2- by 2-inch spacing in the flats and (b) uncrowded, the plants were shifted to increasingly larger pots before crowding became apparent.

By the middle of March, small buttons had formed in a majority of the crowded plants as shown in Fig. 3. In contrast to the uncrowded

FIG. 3. Comparison of cauliflower plants grown under crowded and uncrowded conditions. The uncrowded plant at the right is in a 10-inch pot.

plants the buttoned plants were much smaller, light green in color and displayed a prominent small white head. The uncrowded plants, on the other hand, were dark green in color, possessed many large leaves and gave no evidence of head formation. At first glance it appeared that crowding had resulted in buttoning while the uncrowded plants were still vegetative. Fig. 3 shows this contrast. However, all of the uncrowded plants were stripped of their leaves and examined for the presence of heads. Comparing head formation of the two treatments, it was evident that it had progressed to about the same degree in both. Approximately half of the uncrowded plants possessed heads the same size as those in the crowded flat. Such a comparison is seen in Fig. 4 which pictures a cross section of one uncrowded plant. Thus it was apparent that crowding had resulted in buttoning but not in pre-

FIG. 4. Comparison of cauliflower grown under crowded and uncrowded conditions: longitudinal section through uncrowded plant.

mature heading of cauliflower. Head formation in the crowded plants appeared to be earlier because of sparse amount of foliage which did not conceal the head.

Effect of Plant-Growing Procedure, Quantity of Nitrogen Applied in the Field, Age of Plant and Time of Field Planting on Growth of Cauliflower in Four New York State Counties:—Results of experiments in the greenhouse, particularly during the winter of 1946–47 indicated that buttoning might be a matter of amount of foliage with respect to head size and not premature-heading. In the spring of 1947, an experiment was designed to combine most of the factors previously studied into one large field experiment. The following factors were involved in a factorial design:

A. Greenhouse temperature at which the plants were grown prior to field setting:
   1. Plants grown at a temperature allowing maximum growth, that is, unhardened (approximately 60 to 70 degrees F).
   2. Plants subjected to 3 weeks of low temperature, that is, hardened (approximately 40 to 50 degrees F).

B. Moisture content of soil used in growing plants prior to field planting:
   1. Sufficient water to allow maximum growth.
   2. Plants checked severely by low soil moisture.

C. Quantity of nitrogen applied in the field:
   1. 5–10–10 fertilizer at 3,000 pounds to the acre plus 250 pounds of nitrate of soda applied as a side dressing at a later date.
   2. 0–10–10 at 3,000 pounds per acre.

D. Age of plants at field planting (or date of seeding):
   1. Old — seeded 2 weeks prior to regular seeding time for a given county.
   2. Normal — regular seeding date for a given area.
   3. Young — seeded 2 weeks after regular seeding date.

E. Date of field planting:
   1. Earliest possible date for a given area.
   2. Two weeks later.

F. Location:
   1. Tompkins County (Ithaca, New York)
   2. Erie County (Eden, New York)
   3. Delaware County (Hobart, New York)
   4. Suffolk County (Riverhead, New York)

Employing a factorial type of design, in which all levels of all factors are combined in all possible ways, there were 48 different treatments for each location with twenty plants per treatment. Differences in planting seasons between the counties resulted in varying seeding and field setting dates for the different areas. Plants for all the locations except Long Island were grown in the greenhouses of the Department of Vegetable Crops at Ithaca. Snowball A was the variety used at all times. A partial summary of data is given in Tables II, III, IV, V, and VI. Because of the effect of low nitrogen on buttoning, the data indicating the effect of the other factors is taken from only the high nitrogen plots.

TABLE II—EFFECT OF QUANTITY OF NITROGEN ADDED IN THE FIELD ON GROWTH OF CAULIFLOWER

Nitrogen Level	Tompkins County			Suffolk County			Erie County	Delaware County
	Per Cent Buttoning	Ave Top Weight (Grams)	Ave Curd Weight (Grams)	Per Cent Buttoning	Ave Top Weight (Grams)	Ave Curd Weight (Grams)	Per Cent Buttoning	Per Cent Buttoning
Low.....	100*	434*	138*	49*	537*	229*	100*	43
High.....	18	1,349	419	37	1,104	520	40	49

*Difference between factor levels are significant at odds greater than 99 to 1.

Low temperature and low moisture variations were initiated on the various treatments at such a time as to allow three full weeks of hardening prior to field setting. Plants grown at a low soil moisture level were watered very sparingly and frequently remained wilted for 2 or 3 days consecutively.

The plants were harvested individually, irrespective of treatment, when they reached maturity. They were tied whenever possible according to usual tying procedure and harvested when maximum head

size was attained without elongation of individual seedstalk branches or peduncles. A buttoned plant was one possessing a head surrounded by insufficient foliage for tying and which could not be considered marketable because of this condition.

Of the factors studied, age of plant at field setting had the most striking effect on buttoning and on total yield. In general, the older the plant at transplanting time, the greater was the amount of buttoning. As shown in Table III, young plants, 4 to 6 weeks old produced the largest number of marketable heads and least number of buttons. However, this effect of age was greatly influenced by other variables as indicated by the number of significant interactions. Temperature and moisture levels during seedling growth modified subsequent buttoning to a greater extent so that within a given age treatment, buttoning incidence fluctuated widely. Where nitrogen deficiency was severe enough to cause buttoning of all plants in the low nitrogen plots, as in Tompkins and Erie Counties, age of plant had no effect.

TABLE III—EFFECT OF AGE OF PLANTS AT FIELD PLANTING ON GROWTH OF CAULIFLOWER UNDER CONDITIONS OF HIGH SOIL NITROGEN

Age of Transplants (Weeks)	Tompkins County			Suffolk County			Erie County	Delaware County
	Per Cent Buttoning	Ave Top Weight (Grams)	Ave Curd Weight (Grams)	Per Cent Buttoning	Ave Top Weight (Grams)	Ave Curd Weight (Grams)	Per Cent Buttoning	Per Cent Buttoning
4–6	3*	1,750*	516*	11*	1,278*	494	2*	8*
6–8	12	1,391	433	42	1,047	546	51	54
8–10	39	905	306	58	988	519	68	85

*Difference between factor levels are significant at odds greater than 99 to 1.

Contrary to the reports of numerous investigators and to what might be expected on the basis of similar research on other vegetables, subjecting cauliflower seedlings to low temperature did not induce premature-heading if the plants were subsequently grown at temperatures favorable for head formation. In fact, Table IV shows that subjecting young plants to approximately 3 weeks of 40 to 50 degrees F decreased buttoning as compared to similar plants grown continuously at 60 to 70 degrees F. Checking the growth of the plants by growing them in soil with low moisture had a similar effect. This effect is indicated in Table V. Both treatments resulted in larger plants at harvest time.

TABLE IV—EFFECT OF GREENHOUSE TEMPERATURE AT WHICH PLANTS WERE GROWN PRIOR TO FIELD SETTING ON GROWTH OF CAULIFLOWER UNDER CONDITIONS OF HIGH SOIL NITROGEN

Greenhouse Temperature (Degrees F)	Tompkins County			Suffolk County			Erie County	Delaware County
	Per Cent Buttoning	Ave Top Weight (Grams)	Ave Curd Weight (Grams)	Per Cent Buttoning	Ave Top Weight (Grams)	Ave Curd Weight (Grams)	Per Cent Buttoning	Per Cent Buttoning
40–50	7*	1,482*	459*	24*	1,221*	556*	29*	46
60–70	29	1,215	378	51	988	485	52	52

*Difference between factor levels are significant at odds greater than 99 to 1.

TABLE V—EFFECT OF MOISTURE CONTENT OF SOIL, USED IN GROWING PLANTS PRIOR TO FIELD SETTING, ON GROWTH OF CAULIFLOWER UNDER CONDITIONS OF HIGH SOIL NITROGEN

Soil Moisture	Tompkins County			Suffolk County			Erie County	Delaware County
	Per Cent Buttoning	Ave Top Weight (Grams)	Ave Curd Weight (Grams)	Per Cent Buttoning	Ave Top Weight (Grams)	Ave Curd Weight (Grams)	Per Cent Buttoning	Per Cent Buttoning
Low.....	16	1,379	422	29*	1,185*	546	43	45
High.....	20	1,318	415	45	1,024	494	37	53

*Differences between factor levels are significant at odds greater than 99 to 1.

Buttoning occurred to a greater extent in the first or early planting. As shown in Table VI the decreased buttoning of the later planting may be due to more favorable conditions for vegetative growth which enables the plant to attain a larger size before head formation.

Table II indicates that a deficiency of nitrogen in the field resulted in buttoning. Vegetative growth was retarded and often foliage was so sparse that heads were exposed almost as soon as they were formed. The extent of the deficiency determined the severity of buttoning.

TABLE VI—EFFECT OF FIELD PLANTING DATE ON GROWTH OF CAULIFLOWER UNDER CONDITIONS OF HIGH SOIL NITROGEN

Planting Date	Tompkins County			Suffolk County			Erie County	Delaware County
	Per Cent Buttoning	Ave Top Weight (Grams)	Ave Curd Weight (Grams)	Per Cent Buttoning	Ave Top Weight (Grams)	Ave Curd Weight (Grams)	Per Cent Buttoning	Per Cent Buttoning
First.....	24*	1,125*	355*	46*	1,205*	605*	46*	59*
Second...	12	1,572	482	29	1,005	435	35	39

*Differences between factor levels are significant at odds greater than 99 to 1.

DISCUSSION AND SUMMARY

The problem of buttoning or abnormally early head exposure of cauliflower appears to be the result of several factors. Contrary to the beliefs of numerous commercial growers, exposing plants to low or below freezing temperatures did not alone induce buttoning.

Holding plants in flats beyond their best transplanting condition increased the tendency to button. Plants set in the field when young (approximately 4 to 6 weeks old) did not button if subsequently grown under conditions favoring vigorous vegetative growth.

Retarding the development of older plants in flats by exposure to low temperature or withholding soil moisture decreased the amount of buttoning and increased the number of marketable heads when the plants were eventually set in the field.

Low soil nitrogen increased the number of buttons formed as compared to those grown where nitrogen was not limiting. This was the result of less vegetative growth and not earlier head formation. The fact that severely stunting cauliflower plants by low temperature exposure or low soil moisture conditions did not result in buttoning in-

dicates that not all checks in growth will result in a buttoned condition as so often claimed.

Plants grown in sand in the greenhouse buttoned when supplied insufficient nitrogenous salts but non-buttoned vigorously vegetative plants of high nitrogen treatments apparently formed heads at the same time. Employing the term "premature" which infers earlier head initiation to refer to the buttoned plants does not appear justified.

Exposing plants to 40 to 50 degrees F for 2 weeks hastened head formation in contrast to plants grown at 70 to 80 degrees F, a temperature too high for normal initiation.

These results offer possible explanations for certain observations regarding cauliflower buttoning. Prevalence of buttoned plants in low spots and areas of shallow topsoil may well be due to nutrient deficiency which retards vegetative growth and fosters earlier appearance of the head which in normal plants is well hidden by foliage. The severity of buttoning losses in cold wet seasons is more likely due, not to the exposure of the plants to these unfavorable conditions, but to the fact that the grower had to hold his plants longer and they were thus too old when set in the field. The wide variation in maturity within cauliflower varieties would account for the varying percentage of buttoning.

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Breeding Peppers Resistant to a Puerto Rican Type of Mosaic[1]

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Growing peppers in Puerto Rico for shipment as fresh fruit during the winter season has been an agricultural enterprise of relative importance since 1925. The peak of shipments was attained in the fiscal year 1930–31 when over 27,000 bushels were exported to the continent. However, since that time exports of this vegetable have decreased markedly due to various causes, among them presumably the most important being the appearance and dissemination of the mosaic disease. In 1938 the senior author who was then agronomist in charge of vegetable crops at the Isabela Substation, made a preliminary survey of the virus disease and reported losses of over 50 per cent of the crop. This report led to the initiation of studies at the main station to determine the nature of the disease and possible means of control or prevention. Three years later Roque and Adsuar (1) published the results of the studies undertaken to determine the nature of this disease. It was indicated that the virus causing pepper mosaic in Puerto Rico was either a described form so far not reported as attacking peppers or a new undescribed entity. Out of 84 varieties of the genus Capsicum tested, only two resulted resistant to the virus, namely; a native hot pepper and a Mexican hot pepper known as Cuaresmeño.

Further studies demonstrated also that not infrequently the disease was liable to be confused with the damage caused by the mite *Tarsonemus latus* Bank. The foliar damage caused by the attack of this mite is somewhat similar to the typical symptoms produced by the virus disease. In fact it was found that in some instances pepper losses reported in certain areas as caused by mosaic were mainly due to mite damage. However, this pest is readily controlled by spraying or dusting with sulphur.

In an effort to develop a marketable pepper variety with resistance to this virus disease, California Wonder which is the standard variety grown in the Island for exportation during the winter season, was crossed with the native hot pepper and with Cuaresmeño. After breeding and selecting for some time with the first cross, it was finally discarded due to the lack of size and quality in the fruit produced in subsequent generations. However, the other cross, California Wonder x Cuaresmeño, proved to be the best adapted for breeding a marketable type of mosaic resistant pepper.

Cuaresmeño, which is very resistant to the Puerto Rican mosaic, is prolific but very pungent. Its fruit is similar in shape to the Pimento pepper, but of smaller size, and with thick and firm flesh. As pungency and disease resistance were found to be inherited as single genetic

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[1]This project has been financed jointly with insular funds and Adams funds alloted by the Agricultural Research Administration from the Office of Experiment Stations.

factors, it seemed relatively easy to breed with the California Wonder cross, some desirable lines or types of mild peppers with resistance to the virus disease.

Accordingly, after several trials, selfing and backcrossing during various generations, a group of outstanding lines of peppers were selected which showed resistance to the virus disease and which produced fruit of acceptable market qualities comparable to California Wonder. Out of this group, lines 6, 13, 19, 21, 43 and 48, have been further selected for their superiority in yield, quality of fruit and disease resistance. These six lines are still undergoing yield tests at the Isabela Substation for the purpose of selecting one or two of the best. Selfings are being continued in order to fix the desirable fruit characteristics and for the purpose of getting the necessary uniformity of type.

TABLE I—TRIALS WITH PEPPER LINES RESISTANT TO A PUERTO RICAN TYPE OF MOSAIC (ISABELA SUBSTATION, 1947)

Resistant Lines	First Trial	Second Trial
	Planted Jan 23 Mean Yield (Pounds Per Plot)	Planted Mar 20 Mean Yield (Pounds Per Plot)
6	45.6	38.9
13	*	41.1
19	62.4	48.0
21	50.4	43.5
43	43.6	*
48	56.2	44.6
California Wonder, check	32.2	32.2
Difference for significance:		
At 5 per cent.............	13.4	12.6
At 1 per cent.............	18.3	16.8

*Not enough seed available to be included in this trial.

As indicated in Table I, yield trials have shown that some resistant lines have outyielded significantly California Wonder by margins varying from 40 to over 90 per cent. Since it will take some time before the final selections of these lines are made, in the meantime line 19 which produces uniform fruit acceptable for the local market, has been released to the Seed Farms Division for increase and distribution in the Island. Further selections are still necessary in order to develop and fix a variety which will produce fruit of marketable qualities for the continental markets.

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Hybrid Vigor and Combining Ability in Eggplants[1]

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In 1947 certain standard varieties and F_1 hybrid eggplants were grown in a test at State College, one purpose of which was to determine further the extent of hybrid vigor in the crop, a problem reported on by Kakizaki (1) and by Nagai and Kida (2) who found the phenomenon evident in crosses between Japanese varieties. Another purpose was to evaluate the performance of F_1 hybrids and to compare the combining ability of varieties. This last mentioned problem appears not to be so great a task with eggplants as it is with corn or tomatoes since there are comparatively few varieties of the former crop in existence.

Materials and Methods

Seven varieties were crossed in all possible combinations; however, five of the seed lots did not germinate properly and consequently only 16 of the possible 21 hybrids were studied. Data on the yield of the parent variety Kissing were not obtained because viable seed of this variety was not procured. The choice of parents, Black Beauty, New York Improved Spineless, Early Long Purple, New Hampshire Hybrid, Florida High Bush, Kissing, and Badger State represents a range of types and included several of the most important varieties.

The F_1 hybrids and the parents were grown in a randomized block arrangement. Data were obtained on total yield, early yield, fruit size, shape of fruit, and weight of plant.

Experimental Results

Total Yields:—The yields of the hybrids are given in Table I together with the individual yields of the parent varieties and the mean yield of the two parents involved in each hybrid. In every case the yield of the hybrid progeny exceeded the mean yield of the parents. The range of increase in yield was from 11 per cent for the cross New York Improved Spineless x Badger State to 153 per cent for the cross New Hampshire Hybrid x Florida High Bush. The mean of all hybrids exceeded the mean of all parents by 62 per cent. That hybrid vigor was exhibited is shown also by the fact that the greatest yielding hybrid out-yielded the greatest yielding parent variety by 17.25 tons per acre, a difference that is statistically highly significant.

Statistically significant differences in yield occurred among the hybrids also. Notably good yielders were Early Long Purple by New Hampshire Hybrid and New Hampshire Hybrid by Florida High Bush. These hybrids produced a yield that exceeded 30 tons per acre.

The data are further summarized in Table II. Production for the parent varieties varied from 11.04 tons per acre for Early Long Purple to 19.90 tons per acre for New York Improved Spineless. Each value

[1]Authorized for publication on December 4, 1947 as paper no. 1408 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

TABLE I—TOTAL YIELD IN TONS PER ACRE FOR PARENT VARIETIES, THE MEAN OF PARENTS AND THE F_1 HYBRIDS

Cross	Female Parent	Male Parent	Mean of Parents	F_1	Per Cent Increase of F_1 Over Mean of Parents	Per Cent Increase of F_1 Over Greater Yielding Parent
Black Beauty × New York Improved Spineless	16.31	19.90	18.11	22.53	24	13
Black Beauty × New Hampshire Hybrid	16.31	18.34	17.33	21.38	23	17
Black Beauty × Badger State	16.31	14.84	15.58	21.29	37	31
New York Improved Spineless × Early Long Purple	19.90	11.04	15.47	25.67	66	29
New York Imp. Spineless × New Hampshire Hybrid	19.90	18.34	19.12	26.62	39	34
New York Imp. Spineless × Florida High Bush	19.90	11.08	15.49	26.81	73	35
New York Imp. Spineless × Badger State	19.90	14.84	17.37	19.30	11	–3
Early Long Purple × New Hampshire Hybrid	11.04	18.34	14.69	30.30	106	65
Early Long Purple × Florida High Bush	11.04	11.08	11.06	25.73	133	132
Early Long Purple × Kissing	11.04	—	—	22.61	—	—
Early Long Purple × Badger State	11.04	14.84	12.94	28.25	118	90
New Hampshire Hybrid × Florida High Bush	18.34	11.08	14.71	37.15	153	103
New Hampshire Hybrid × Kissing	18.34	—	—	23.75	—	29*
New Hampshire Hybrid × Badger State	18.34	14.84	16.59	22.43	35	22
Florida High Bush × Kissing	11.08	—	—	23.79	—	115*
Kissing × Badger State	—	14.84	—	21.70	—	46*
Significant difference at 5 per cent level for parents and hybrid—9.37						
Mean	16.11	14.88	15.50	24.95	62	—

*Kissing not grown in the test in 1947—is similar to Early Long Purple in yield.

TABLE II—TOTAL YIELD IN TONS PER ACRE FOR PARENT VARIETIES AND FOR THEIR F_1 HYBRID PROGENIES

Name of Parent	Parents	Mean of Parents	Mean of F_1 Hybrids	Per Cent Increase of Hybrids Over Common Parent	Per Cent Increase of Hybrids Over Mean of Parents
Black Beauty	16.31	17.00	21.70	33	28
New York Improved Spineless	19.90	16.86	24.18	22	43
Early Long Purple	11.04	13.54	26.51	140	96
New Hampshire Hybrid	18.34	16.48	29.94	47	63
Florida High Bush	11.08	13.75	28.37	156	106
Kissing	—	—	22.96	—	—
Badger State	14.84	15.62	21.29	43	36

in the "Mean of Parents" column of Table II represents the average yield of all varieties involved in crosses with the particular parent given in the first column. For example the first value in the "Mean of Parents" column, 17.00, is the mean yield in tons per acre of the parents in all crosses involving the variety Black Beauty. The "Mean of Hybrids" column gives the average yield of all hybrids which have the particular variety given in column 1 as a common parent. The value 21.70 is the mean yield in tons per acre of all F_1 hybrids having Black Beauty as one parent. The increase in mean yield of the hybrids over the yield of the common parent ranges from 22 to 156 per cent. Of greater significance is the increase in mean yield of the hybrids over the mean of the parents where the range of increase is from 28 to 106 per cent. In regard to combining ability it might be pointed out that the two series of common parent crosses with the lowest "Mean of Parents" yield, those involving Early Long Purple and Florida

High Bush, produced exceptionally high yielding F_1 progenies. Early Long Purple appears to produce high yielding F_1 progenies and Florida High Bush, a variety generally considered too late for Pennsylvania, likewise produced high yielding F_1 progenies. It appears that a somewhat inferior strain of Black Beauty was used in the test and this inferiority seems to be reflected in the F_1 progenies.

Early Yield:—Early yield is the weight in pounds of fruit per acre obtained from the first two of the four harvests that were made. The data are presented in Table III (column 3) where it may be noted that the mean yields of the parents and the F_1 progenies are 4.11 and 7.98 tons per acre, respectively. The difference in yield, 3.87 tons per acre, was found by the F test to be statistically highly significant. Thus the hybrids produced a 94 per cent greater early yield than did their parents.

TABLE III—Total Yield and Early Yield in Tons Per Acre, Number of Fruit Per Plot, Average Size of Fruit in Pounds and Weight of Plants Per Plot in Pounds for Varieties and F_1 Hybrids

Parent Variety or Cross	Total Yield	Early Yield	Number of Fruit	Average Size of Fruit	Weight of Plants
Black Beauty	16.31	4.85	19.0	1.58	4.40
New York Improved Spineless	19.90	6.59	22.0	1.63	5.88
Early Long Purple	11.04	2.50	27.0	0.70	3.25
New Hampshire Hybrid	18.34	4.25	37.5	0.90	3.00
Florida High Bush	11.08	1.52	12.8	1.58	8.73
Kissing	—	—	—	—	—
Badger State	14.84	5.06	24.0	1.65	6.80
Black Beauty ×New York Imp. Spineless	22.53	6.43	36.8	1.13	5.40
Black Beauty ×New Hampshire Hybrid	21.38	6.64	33.5	1.28	4.95
Black Beauty ×Badger State	21.29	3.65	20.8	1.25	4.40
New York Imp. Spineless ×Early Long Purple	25.67	8.11	41.0	1.05	5.85
New York Imp. Spineless ×New Hampshire Hybrid	26.62	7.95	32.5	1.40	4.63
New York Imp. Spineless ×Florida High Bush	26.81	7.80	31.0	1.60	9.03
New York Imp. Spineless ×Badger State	19.30	6.70	23.8	1.48	6.08
Early Long Purple ×New Hampshire Hybrid	30.30	8.49	64.3	0.88	4.63
Early Long Purple ×Florida High Bush	25.73	8.17	46.3	1.06	6.78
Early Long Purple ×Kissing	22.61	7.46	59.0	0.70	5.45
Early Long Purple ×Badger State	28.25	11.82	43.8	1.20	7.88
New Hampshire Hybrid ×Florida High Bush	37.15	11.11	50.5	1.38	5.55
New Hampshire Hybrid ×Kissing	23.75	8.22	60.0	0.73	3.28
New Hampshire Hybrid ×Badger State	22.43	9.86	32.5	1.30	3.28
Florida High Bush ×Kissing	23.79	10.24	42.0	1.05	5.18
Kissing ×Badger State	21.70	8.22	44.3	0.90	4.68
Significant Difference	9.37	3.63	14.28	0.23	3.84
Mean for Varieties	15.25	4.11	23.71	1.34	5.34
Mean for Hybrids	24.95	7.98	41.55	1.15	5.45

Statistically significant differences in early yield also occurred among the hybrids. Early Long Purple x Badger State, New Hampshire Hybrid x Florida High Bush and Florida High Bush x Kissing produced exceptionally high early yields.

Table IV gives a further summary of the early yield data. It is somewhat surprising to note that the three greatest yielding hybrid series are progeny of the lowest yielding parent varieties. This suggests a negative correlation between early yield in parent varieties and early yield in their F_1 progenies.

Number of Fruits:—The data are represented in Table III (column 4). Statistically significant differences in number of fruit per plot

TABLE IV—EARLY YIELD IN TONS PER ACRE FOR PARENT VARIETIES AND FOR F_1 HYBRID PROGENIES OF THE PARENT VARIETIES

Name of Parent	Parents	Mean of Parents	Mean of F_1 Hybrids	Per Cent Increase of Hybrids Over	
				Common Parent	Mean of Parents
Black Beauty	4.84	5.08	5.57	15	10
New York Improved Spineless	6.59	5.11	7.35	12	44
Early Long Purple	2.50	3.43	8.82	253	157
New Hampshire Hybrid	4.25	4.18	8.77	106	110
Florida High Bush	1.52	2.98	9.31	513	202
Kissing	—	—	8.54	—	—
Badger State	5.06	4.80	8.06	59	68

occurred among the varieties and also among the F_1 progenies. The average number of fruits per plot for the parent varieties is 23.71, while the average number of fruits per plot for the F_1 hybrids is 41.55. The difference between these yields is highly significant.

The average number of fruits per plot produced by the F_1 progenies of each of the parent varieties was: Black Beauty, 30.4; New York Improved Spineless, 51.5; Early Long Purple, 45.6; New Hampshire Hybrid, 42.5; Florida High Bush, 51.3; and Badger State, 33.0. The small-fruited varieties Early Long Purple, New Hampshire Hybrid, and Kissing which are prolific, gave rise to F_1 progenies that were above average in number of fruits per plot. The late variety Florida High Bush failed to produce many fruits; however, its F_1 progenies were fairly prolific. Substantial increases in yields of progenies over the common parent are found in the other large-fruited varieties also. It may be noted in Table III that in crosses where both parents are very prolific the F_1 progeny is exceptionally prolific, for example Early Long Purple x New Hampshire Hybrid.

Fruit Size:—Great difference in size of fruit were found among the parent varieties and also among the F_1 progenies (Table III, column 5). The size of the fruit of Kissing which was not grown in 1947 is approximately equal to the size of the fruit of Early Long Purple. Thus there are three large-fruited varieties and three small-fruited ones. The average fruit size of F_1 progenies is 1.34 pounds while the fruit size of the mean of the parents is 1.15 pounds; the difference in weight is 0.19 pound and is not significant. Only very slight differences in weight per fruit were found in specific comparisons of F_1 hybrids with the mean of the parents.

Weight of Plant:—The weight of plant per plot was obtained several days after a frost had killed the plants. At that time the leaves were dry but none had fallen off. The data are given in Table III (column 6). Great differences in weight of plant are found among the varieties. The smallest of the varieties are less than half as large as the largest. Likewise there are great differences among the hybrids; in those cases where F_1 progenies can be compared with the mean of their parents the weight of plants per plot for the hybrids is 18 per cent greater than is the weight of plants per plot for the mean of the parents. Positive correlation is apparent between size and parents and plant size in their progenies.

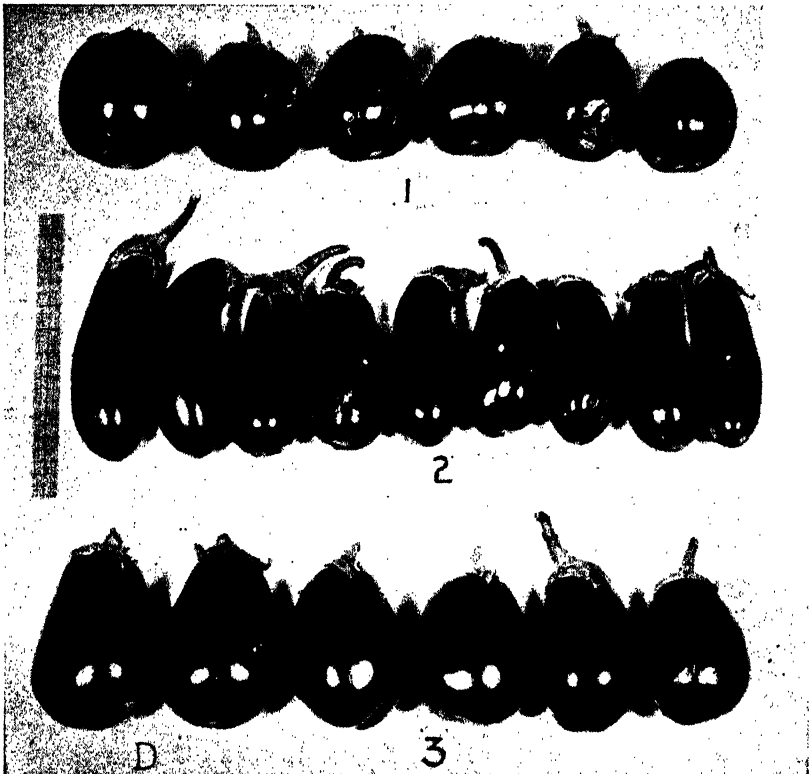

FIG. 1. 1, New Hampshire Hybrid; 2, Early Long Purple and 3, F_1 of New Hampshire Hybrid x Early Long Purple. In general a greater degree of uniformity was noted in the hybrids than in the parent varieties. While the long shape of Early Long Purple is not especially desirable the shape of the F_1 is probably satisfactory.

INTER-RELATION OF CHARACTERS

Statistical analysis of the relation between characters has not been made; certain associations, however, are of interest and will be discussed briefly. In Table III the total and early yield per acre, the number of fruits per plot, the average size of fruits, and the weight of plants per plot are given. There is apparent a positive correlation between total yield and early yield in F_1 hybrids as well as in the parent varieties. The three hybrids producing the greatest total yield were Early Long Purple x New Hampshire Hybrid, Early Long Purple x Badger State and New Hampshire Hybrid x Florida High Bush. These same three hybrids are among the greatest producing hybrids for early yield also. Similarily those hybrids that produce a low total yield tend to produce a low early yield.

Yield in eggplants is determined by number and size of fruits. Since in general the size of the fruit of the F_1 hybrids is approximately the

size of the fruits of the respective mean of the parents it follows that the increase in yield of hybrids over the average of the parents must result from an increase in number of fruits. In the F_1 hybrid Early Long Purple x New Hampshire Hybrid the weight per fruit for the parent varieties in .70 and .90 pound respectively, while the weight per fruit for the hybrid is .88 pound. In this cross the hybrid outyielded the average of parents by 106 per cent and since fruit size varies only slightly the increase in yield is due to increase in number of fruits.

The F_1 hybrids exceeded the varieties only slightly in weight of plants per plot. This was somewhat noteworthy since in the early part of the season the hybrids were very evidently more vigorous than their parents. It was observed that, in those lots of plants that set a heavy crop of fruit, plant growth in the late season was retarded as compared with those that did not set many fruits. In other words, the expression of hybrid vigor with regard to plant size probably would have been considerably greater had the effect of fruit production been eliminated. It would seem thus that there actually is considerable association between yield and size of plant.

Discussion

Since hybrid vigor is pronounced in the eggplant the question as to the feasibility of its utilization in commercial production arises. Because early production as well as total production is increased and because a greater degree of uniformity is obtained the possible monetary gain to the grower is fairly great. The technique of producing hybrid seed is not difficult; however, vigorous, large, early-set plants are a prerequisite. Generally best results are obtained from the first bud formed in each cluster. Kakizaki (1) reports that in certain varieties the fruits produced 2,500 seeds on the average. Thus, if favorable results are obtained, the seed from only a few fruits would be sufficient to plant an acre.

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Effect of Irrigation on the Yield of Onion Seed

By JOHN H. MACGILLIVRAY, *University of California, Davis, Calif.*

AN important portion of American onion seed is produced in the West, where there is a deficiency of summer rainfall and where water supplies have been developed for irrigation. Studies of the effect of irrigation on the yield of the fresh crop give evidence that irrigation would increase yield. In this case the majority of the plant's roots were in the top 2 feet of soil. Growers follow radically different practices in irrigating onions for seed. Some use little or no water and others apply generous amounts. The present study was undertaken to obtain information regarding the effect of irrigation on onion-seed production.

REVIEW OF LITERATURE

The effect of irrigation on the production of onion seed has not been reported in the literature. There are three references, however, to the effect of irrigation on the yield of onion bulbs.

MacGillivray and Doneen (3) in two years' experiments with early and late onions at Davis, found that irrigation increased yield of early varieties 125 per cent and late varieties 245 per cent. Early varieties were affected less because they were planted and harvested earlier, and therefore made more growth during the period of winter rains. In these experiments, yields from irrigated and nonirrigated plots were compared. Irrigation experiments have also been conducted in New Mexico (1) and Texas (2) but in neither of the above experiments was there a nonirrigated treatment, so differences between treatments were smaller.

METHODS

The studies whose results are reported in this paper were made at Davis, California, in 1943 to 1945. A sedimentary soil of the Yolo loam type was used. Winter rainfall in this area was 15.5 inches from July 1, 1943, to July 1, 1944, and 15.4 inches in 1944–1945. Little or no rainfall occurs during the months of May or June or, in fact, until October. Rainfall during the winter months usually wets the soil to field capacity by spring, to the depth of 6 feet or more. The Yellow Sweet Spanish bulbs for the 1944 crop were planted November 20, 1943; for the 1945 crop, December 11, 1944. Average-sized bulbs were planted in a trench 4 inches deep, and were spaced 3 feet by 4 inches. The irrigation treatments are indicated by: (A) plots which were not irrigated throughout the test, but did receive some winter rain; (B) plots which received more than sufficient irrigation water to obtain maximum yield; and (C) plots which received sufficient irrigation water to produce a near maximum yield. The crop was grown with good cultural practices. The soil was sampled for soil moisture before and after each irrigation. The data found appear in Fig. 1. The soil moisture data are expressed in inches of available water rather than in percentages. Field capacity and permanent wilting percentage were determined on these soils, and the inches of available water held

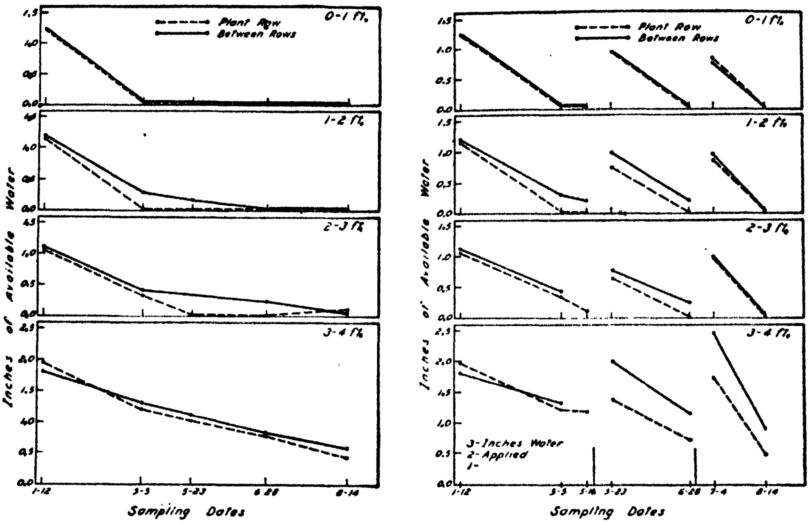

FIG. 1. Soil moisture extraction curves of the onion-seed plots (1945). Graph shows available water for each foot of depth and time of removal by the roots. A non-irrigated plot is given at the left and an irrigated plot at the right.

at field capacity were determined from a volume weight of 85 pounds per cubic foot. Inches of available water are easier to correlate with rainfall and irrigation application data. The soil used in this study at field capacity held between 1.4 and 1.5 inches of available water per foot of depth in the top 3 feet of soil and slightly more in the fourth foot. As the onion fruit capsules matured and showed some tendency to open, the individual heads were harvested by hand. The heads were dried on canvas in the sun, and the seed was obtained by the usual seed-saving method.

Discussion

Onion-seed yields were increased both years by irrigation, and the differences in both cases were probably sufficient to justify some irrigation. The yields obtained on the (B) treatment, slightly exceeded the usual yield of 400 to 600 pounds per acre. The wet treatment in 1944 produced 35 per cent greater weight of seed than the unirrigated, and, similarly, in 1945 the increase was 80 per cent. Probably three or four irrigations are desirable, with a minimum application of 10 inches of water. Fig. 2 indicates the relative growth of the extreme treatments. Irrigation close to the harvest period tended to cause the seedstalks to fall over; this difference is noticeable from the tendency of the seedstalks to fall over as shown in Fig. 2. The wet treatment produced larger plants and, in general, larger and more numerous heads. Some measurements were made of seedstalk growth. This growth was usually in proportion to the amount of water added to the plot. Each year the plants bloomed about the first week in May, and the seed was harvested the middle of August.

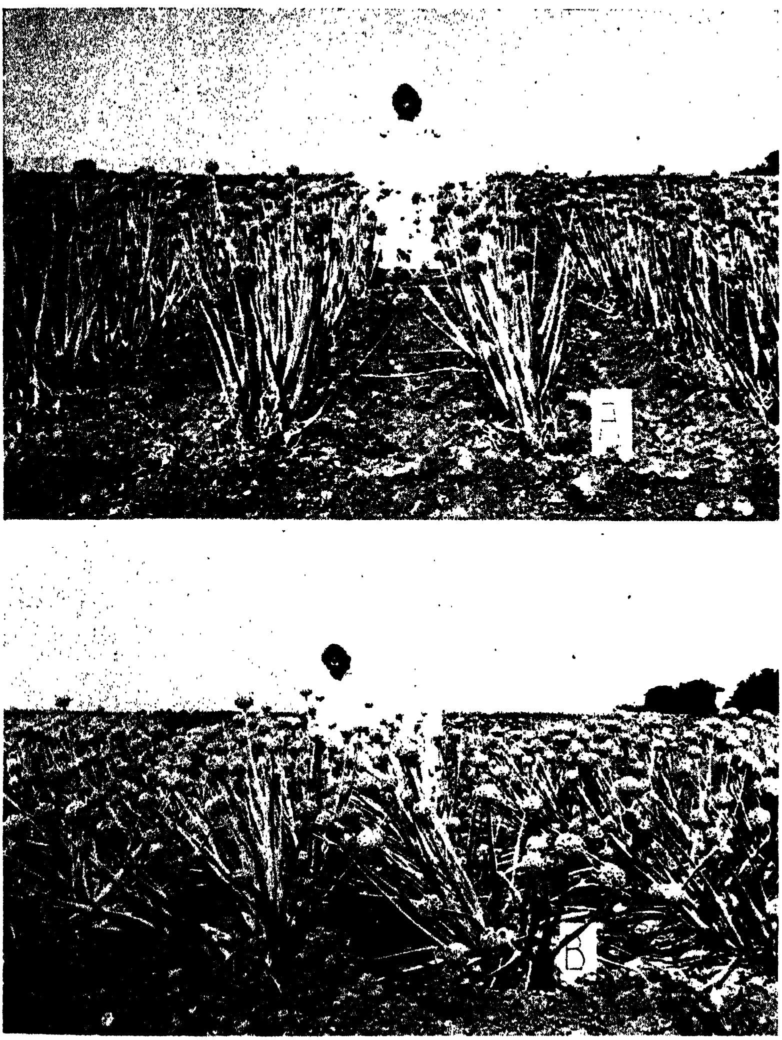

FIG. 2. Onion-seed plots grown without irrigation (A) and an ample amount of irrigation water (B).

In the crops harvested, there has been a tendency for the vegetative part of the plant to have its earliness affected by irrigation treatment. Both white potatoes and market-ripe onions have given definite indications of maturing sooner when insufficiently watered. In 1944 there was some indication that seed heads matured sooner on the dry than on the wet plots. The 1945 results failed to confirm this effect.

High seed germination is an important characteristic of good vegetable seed. Under conditions of commercial production, there is con-

siderable variation in the germination of seed from different fields. Data reported in this paper gave surprisingly similar germination for all three treatments. Usually a germination of 85 per cent is to be desired, and all of these treatments were slightly below the desired percentage. In both cases the medium treatment (C) gave the highest percentage germination.

Table I also gives data on the weight of 100 seed from the three treatments. Since onion seeds are small in size, the weight of this number of seed is less than ½ gram. The dry treatment (A) always produced the smallest seed and the medium (C) was always the highest. The differences in weight were small — .028 grams for the seed harvested in 1944 and .037 for that harvested in 1945.

TABLE I—EFFECT OF IRRIGATION ON THE YIELD AND SEED QUALITY OF YELLOW SPANISH ONION SEED (1944 AND 1945)

Treatment	Inches of Water Applied	Number of Irrigations	Pounds of Seed Per Plot	Pounds of Seed Per Acre	Per Cent Germination of Seed	Weight of 100 Seed (Grams)	Per Cent by Weight of Heads at First Harvest
			Seed Crop for 1944—Three Replications				
A—dry	0	0	2.02	467	83.3	0.394	41.1
B—wet	15	5	2.72	629	82.1	0.421	31.8
C—medium	5	2	2.42	560	84.6	0.422	26.6
Least significant difference: Odds 19 to 1			N.S.*†	—	N.S.†	N.S.†	N.S.†
			Seed Crop for 1945—Four Replications				
A—dry	0	0	1.91	387	79.8	0.352	40.6
B—wet	15	5	3.53	698	79.6	0.356	36.4
C—medium	6	2	2.36	471	81.9	0.389	42.9
Least significant difference: Odds 19 to 1			0.98	194	N.S.†	0.002	N.S.†

*Odds are 13 to 1.
†Nonsignificant results are indicated by N.S.

The soil moisture removal graphs are given in Fig. 1. The dry treatment indicates that water was removed from the top 4 feet of soil, and that about 0.6 inches were left available in the top 4 feet of soil on August 14. Soil samples probably should have been taken at least a foot deeper to determine whether there was any deeper root penetration. Since, in the fresh onion crop most of the roots are found in the top 2 feet of soil, the penetration of the roots to a depth of 4 feet for onion bulbs is of interest. In the dry treatment there is a gradual removal of water from each foot zone of soil. When the available water has been entirely removed, the lines in the graph level off at the P.W.P. or where there is no available water, as in the surface foot of soil (Fig. 1). The removal of water from the irrigated treatment in this figure is similar to the previous figure, except that there have been two irrigations. Usually a week lapses between the samplings before and following an irrigation. It is impossible to sample immediately after the plots have been watered; therefore the points on the graph are below field capacity after an irrigation. There is every reason to believe that after each irrigation the soil was filled to field capacity in

the top 2 to 3 feet. Most of the water was removed from the top 4 feet at the time of irrigation and on August 14, there was less than ¾ inch of available water in the top 4 feet.

The seed from these experiments was stored in order to produce a crop of bulbs as well as to study the effect of storage on their germination. Germination tests were made each fall after the harvest of the seed by the State Seed Laboratory, and similar tests were made in October 1947 of both lots of seed. The 1944 seed had been stored 3 years and the 1945 seed 2 years. The 1944 seed was stored most of the time at 32 degrees F, but there were times when refrigeration was not available. During part of the period, the seed was at room temperature, as was the 1945 seed. After the storage period there was no significant difference in germination. There was little difference in the germination of the 1945 crop either in the fall of 1945 or that of 1947. The 1944 crop suffered more severe reduction in germination from storage than did the 1945 crop. The (B) treatment seed suffered an average reduction in germination of 21 per cent, (A) 13 per cent, and (C) 11 per cent. All lots of seed were planted in 1945 for bulb production. Average-sized transplants were grown two rows per bed and field-planted on April 6, 1945. There was no significant difference in the yield of bulbs from the nine lots of seed produced in 1944 and the 12 lots produced in 1945.

SUMMARY

Irrigation of onion-seed bulbs at Davis gave increased yields of seed. An application of a minimum of 10 inches of water in this area would seem desirable. Irrigation did not materially affect percentages of germination or size of seed.

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The Influence of Various Summer Planting Dates on the Yield of Broccoli Strains

By J. E. Knott and G. C. Hanna, *University of California, Davis, Calif.*

The quality of broccoli is best if the flower-bud clusters reach market maturity in cool weather, although the early growth may take place at high temperatures. Thus in the Sacramento Valley of California it would be possible to plant broccoli at any time during the summer, fall and early winter months if the yields from all such plantings were satisfactory. Preliminary experiments had shown that fall and early winter planting dates gave very poor yields due to the effect of the cold weather in checking the growth of the plants. The problems involved in broccoli production in the Sacramento Valley are the selection of suitable strains and planting periods for those strains in order to provide a sequence of supply over a long period. The experiments were not designed to compare strains from different sources as in the work of Brittingham (1), but rather the behavior of typical ones having different seasons of maturity.

Methods

The 1945–46 and 1946–47 experiments were laid out in a split plot Latin square design, with three planting dates, each replicated three times. The strains used are listed in Tables I and II.

DeCicco, Group I, Freezers', medium, late and Morse early are standard strains. Two early and two medium strains were used in this

TABLE I—The Average Total Weight of Side Shoots per Plant as Affected by Strain and Date of Seeding

Strain	1945–46				1946–47			
	Jul 1 (Lbs)	Aug 1 (Lbs)	Sep 1 (Lbs)	Average for Strain (Lbs)	Jul 1 (Lbs)	Aug 1 (Lbs)	Sep 1 (Lbs)	Average for Strain (Lbs)
Very Early								
Group I	0.92	0.53	0.27	0.57	1.05	0.41	0.26	0.57
DeCicco	0.75	0.32	0.11	0.40	1.05	0.45	0.24	0.58
Freezers'	1.02	0.60	0.17	0.60	—	—	—	—
Early								
Morse Early (C-0162)	0.74	0.38	0.14	0.42	0.96	0.51	0.22	0.56
Morse Early (C-5126)	0.87	0.31	0.15	0.44	1.06	0.66	0.29	0.67
Midseason								
Medium (Asgrow)	0.85	0.56	0.38	0.59	1.08	0.97	0.33	0.79
Medium (Morse)	0.80	0.60	0.39	0.60	1.12	0.92	0.39	0.81
Late								
Late	0.53	0.63	0.29	0.48	1.01	0.71	0.09	0.60
Average at each seeding date	0.81	0.49	0.24		1.04	0.66	0.26	
Difference required between	Odds of 19:1		Odds of 99:1		Odds of 19:1		Odds of 99:1	
(a) seeding date averages	0.15		0.35		0.11		0.25	
(b) strain averages	0.10		0.14		0.09		0.12	

TABLE II—THE AVERAGE TOTAL YIELD PER PLANT AS AFFECTED BY STRAIN AND DATE OF SEEDING

Strain	1945-46 Jul 1 (Lbs)	1945-46 Aug 1 (Lbs)	1945-46 Sep 1 (Lbs)	1945-46 Average for Strain (Lbs)	1946-47 Jul 1 (Lbs)	1946-47 Aug 1 (Lbs)	1946-47 Sep 1 (Lbs)	1946-47 Average for Strain (Lbs)
Very Early								
Group I	1.33	1.04	0.58	0.98	1.45	0.85	0.58	0.96
DeCicco	1.19	0.80	0.45	0.81	1.57	0.90	0.58	1.02
Freezers'	1.44	1.11	0.54	1.03	—	—	—	—
Early								
Morse Early (C-0162)	1.26	1.03	0.51	0.93	1.58	1.12	0.70	1.13
Morse Early (C-5126)	1.40	1.02	0.48	0.96	1.61	1.28	0.68	1.19
Midseason								
Medium (Asgrow)	1.30	1.07	0.71	1.03	1.60	1.48	0.69	1.26
Medium (Morse)	1.27	1.06	0.70	1.01	1.62	1.47	0.77	1.29
Late								
Late	1.36	1.55	0.89	1.27	1.96	1.46	0.61	1.34
Average at each seeding date	1.32	1.08	0.61		1.62	1.22	0.66	
Difference required between	Odds of 19:1		Odds of 99:1		Odds of 19:1		Odds of 99:1	
(a) seeding date averages	0.19		0.43		0.09		0.21	
(b) strain averages	0.13		0.17		0.16		0.21	

experiment. The Freezers' strain was used in 1945–46 but not in 1946–47. The strains have been arbitrarily separated into very early, early, midseason, and late groups. The seed trade usually lists them as early, medium, and late strains but such a classification is not adequate.

The seed was drilled in rows on 40 inch centers and the plants thinned to 18 inches in the row. This thinning was done in two steps in order to have as uniform plants as possible. In 1945–46 there were 20 plants in each replicate. In 1946–47 twice that many were used. The broccoli was grown on a highly productive Yolo silt loam. No fertilizer was used in 1945–46 but the 1946–47 planting received 100 pounds of nitrate of soda per acre as a side-dressing on September 18, 1946.

The centers and shoots were cut as the buds reached maturity, the larger leaves were removed and the stems cut to an 8-inch length before weighing. Both lateral and sub-lateral shoots were harvested as long as the diameter of the stems was about ½ inch or more, and that of the bud clusters 1 inch or more. This smallest size would be satisfactory for freezing or for bunching for California markets but would not do for shipment to eastern markets. Harvests were made at 3- to 10-day intervals depending on the weather and rate of development of the crop. By mid-March or earlier the size of the product on all plots was such as to be not worth harvesting.

The analyses of variance for the data are presented in Table III.

RESULTS

Data on the average weight of the center head, average weight of the individual side shoots, average number of side shoots per plant, and the harvest periods have been presented elsewhere (2).

TABLE III—Analysis of Variance of the Data

Source of	Degrees of Freedom	Average Yield of Side Shoots Per Plant		Average Total Yield Per Plant	
		Mean Square	F	Mean Square	F
		1945–46			
Columns	2	0.012	N.S.	0.020	N.S.
Replications	2	0.097	N.S.	0.217	N.S.
Planting dates	2	1.985	130.36**	3.159	140.26**
Error a	2	0.015	——	0.022	——
Strain	7	0.065	5.79**	0.146	8.35**
Strain ×planting date	14	0.041	3.70**	0.036	2.06*
Error b	42	0.011	——	0.017	——
		1946–47			
Columns	2	0.002	N.S.	0.001	N.S.
Replications	2	0.006	N.S.	0.018	N.S.
Planting dates	2	3.246	494.17**	4.982	1,059.03**
Error a	2	0.006	——	0.004	——
Strain	6	0.097	9.75**	0.180	12.09**
Strain ×planting dates	12	0.041	4.12**	0.065	4.37**
Error b	36	0.010	——	0.015	——

*Exceeds the 5 per cent point.
**Exceeds the 1 per cent point.

The average total weights of side shoots per plant for the different strains in each of the two years are presented in Table I. In 1945–46 the side shoot yields of Freezers', the mediums, and group I were all comparable. However in 1946–47 the mediums gave the greatest total yield of side shoots. The weight of side shoots per plant decreased rapidly as the planting date was delayed from July 1 to September 1. This is the result of a reaction to climatic conditions and also to the longer harvesting period from the July 1 seeding.

While we cannot compare by the method of analysis used the performance of the strains within any one planting date, it appears that the mediums outyielded the others at the August 1 and September 1 planting dates especially in 1946–47.

The average total yield per plant for the different strains is given in Table II for both years. The total yield represents the side shoots plus the center head.

In 1945–46, the late strain gave the greatest average total yield for the season while DeCicco was the lowest yielding strain. The high total yield of the late strain was due to the large size of the center head with its heavy stem as compared to these characteristics in all the other strains. There were no differences between the remainder of the strains. In the following year also the quicker-maturing the strain the lighter was the total yield.

There was a consistent decline in the total yield as the planting was delayed later in the season. The plant growth also decreased. Observations indicated that the plants started July 1 made half again as much plant growth as those started August 1 and the latter about 50 per cent more than those planted on September 1.

The significant interaction (Table III) between planting date and strain is due to the fact that the very early and early strains were much more strikingly reduced in their yield, especially of side shoots,

by the August 1 and September 1 plantings compared to that of July 1 than were the midseason strains. The effect of planting dates on decreased side shoot production in the late strain was not very great in 1945–46 but more pronounced than in any other strain in 1946–47.

TABLE IV—DATE BY WHICH 75 PER CENT OF THE CENTER HEADS OF EACH STRAIN HAD BEEN HARVESTED

	Planted Jul 1		Planted Aug 1		Planted Sep 1	
	1945	1946	1945	1946	1945	1946
Very Early						
Group I	Oct 5	Oct 7	Nov 20	Nov 21	Jan 23	Feb 10
DeCicco	Oct 5	Oct 2	Nov 20	Nov 13	Jan 23	Feb 17
Freezers'	Oct 5	———	Nov 20	———	Jan 23	———
Early						
Morse Early (C-0162)	Oct 17	Oct 21	Jan 2	Dec 13	Jan 31	Feb 17
Morse Early (C-5126)	Oct 17	Oct 21	Dec 17	Dec 13	Jan 31	Feb 17
Midseason						
Medium (Asgrow)	Dec 3	Dec 2	Jan 15	Feb 10	Feb 16	Feb 17
Medium (Morse)	Dec 11	Dec 2	Jan 15	Feb 10	Feb 16	Feb 24
Late						
Late	Feb 26	Feb 24	Mar 6	Mar 5	Mar 6	Mar 5

It is apparent in Table IV that the strains used in this work fall into the four groups suggested. There is a fairly close similarity between the two years in the dates by which any given strain had reached the stage at which 75 per cent of the center heads had been harvested. When the planting was delayed until September 1, there was much less difference between the dates at which the various strains reached this stage of harvest than was the case in the July 1 planting. The cool weather tends to obliterate the differences between strains.

The length of the harvesting period for the various strains at the three planting dates are shown in Fig. 1. By comparing the dates in Table IV

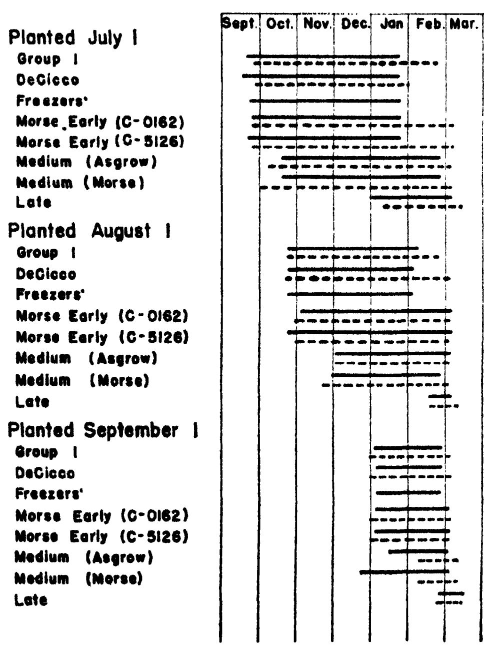

FIG. 1. Period of harvest from broccoli strains planted on three different dates. The solid line represents the 1945–46 season, the dotted line the 1946–47 season.

with Fig. 1, it is possible to see what part of the harvesting period was primarily of side shoots. Side-shoot harvesting started soon after the first center heads were cut and continued to the end of the periods indicated. The dates at which the first marketable heads were found do not differ greatly between the very early and early strains. The tendency for the very early strains to cease production of harvestable material sooner than the others is clearly shown in the July 1 and August 1 plantings.

Summary

If it is desired to harvest broccoli in the Sacramento Valley in the early fall then the very early or early strains are preferable and should be seeded in July. For late fall and winter harvest, the midseason strains are best and could be seeded until early in August.

September 1 is too late a date for the direct seeding of broccoli in this area.

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Effects of the Sodium and of the Chloride Ion in the Nutrition of the Table Beet in Culture Solutions[1]

By G. J. RALEIGH, *Cornell University, Ithaca, N. Y.*

MANY investigators have suggested that on many soils beets and other halophytes are responsive to sodium applications. On the other hand, there is evidence that under some conditions halophytes may respond to applications of chloride salts. These experiments were initiated to determine the response in various culture solutions of a strain of Detroit beet being used in field experiments. For relatively recent reviews on the role of sodium and of chlorine in plant nutrition, see Harmer and Benne (2), and Haas (1).

PROCEDURE

The experiments were carried out in the greenhouse at Ithaca. With the exception of experiment 5, temperatures for the most part ranged between 60 and 70 degrees F. Seed was sown in quartz sand and watered with Hoagland's nutrient solution No. 1 consisting of KH_2PO_4, 0.001M; $MgSO_4$, 0.002M; $Ca(NO_3)_2$, 0.005M; and KNO_3, 0.005M. A_5 solution (lacking Cl) was used to supply 0.5 part per million B; 0.5 part per million Mn; 0.05 part per million Zn; 0.02 part per million Cu; and 0.01 part per million Mo. When the plants were of sufficient size, they were transferred to a similar aerated solution in asphalt painted iron containers. After they had attained a height of about 3 inches, they were transferred to experimental solutions. Distilled water and reagent grade chemicals were used for all stages of growth.

In each of the five experiments, Hoagland's solution No. 1 was used as a check. In these experiments when additions were made to a solution, a sufficient quantity of a concentrated solution of the chemical was added to give the molarity indicated. In experiments 1 and 2 treatments included the following individual additions to the Hoagland solution: KCl, 0.005M; K_2SO_4, 0.0025M; NaCl, 0.005M; and Na_2SO_4, 0.0025M. In experiment 3 the following solutions were used: Hoagland's solution; Hoagland's solution plus NaCl, 0.002M; Hoagland's solution plus NaCl, 0.004M; Hoagland's solution plus Na_2SO_4, 0.001M; Hoagland's solution plus Na_2SO_4, 0.002M; a solution similar to Hoagland's solution except that one-half of the Mg came from $MgCl_2$; a solution like Hoagland's solution except that the amount of KNO_3 was reduced to 0.003M and $NaNO_3$, 0.002M was added; a similar solution except that the KNO_3 was reduced to 0.001M and $NaNO_3$, 0.004M was added. In experiment 4 the solutions used were as follows: Hoagland's solution; a similar solution except that one-half of the Mg came from $MgCl_2$; Hoagland's solution plus NaCl, 0.002M; and a solution made up to reduce the amount of SO_4 yet supply Na. It contained KH_2PO_4, 0.001M; $MgSO_4$, 0.001M;

[1]Paper No. 292. Department of Vegetable Crops, Cornell University, Ithaca, N. Y.

TABLE I—AVERAGE WET WEIGHT YIELD OF BEETS AND OF TOPS IN GRAMS (EXPERIMENTS 1 THROUGH 5)

Solution	Experiment 1		Experiment 2		Experiment 3		Experiment 4		Experiment 5			
									50 to 60 Degrees F		70 to 80 Degrees F	
	Beets	Tops	Beets	Tops	Beets	Tops	Beets	Tops	Beets	Tops	Beets	Tops
Hoagland's solution	129.6	141.7	69.2	124.3	251.9	221.7	88.8	121.5	85.2	98.6	196.3	134.9
Hoagland's solution plus KCl, 0.005M	168.4**	185.4*	98.8*	199.9*	—	—	—	—	—	—	—	—
Hoagland's solution plus K_2SO_4, 0.0025M	139.1	140.3	87.0*	162.5	—	—	—	—	—	—	—	—
Hoagland's solution but KNO_3, 0.003M and $NaNO_3$, 0.002M	—	—	—	—	317.1	253.1	—	—	—	—	—	—
Hoagland's solution but KNO_3, 0.001M and $NaNO_3$, 0.004M	—	—	—	—	297.1	232.4	—	—	—	—	—	—
Hoagland's solution plus NaCl, 0.002M	—	—	—	—	433.0**	359.2**	100.6	157.2*	—	—	—	—
Hoagland's solution plus NaCl, 0.004M	—	—	—	—	417.0**	356.4**	—	—	—	—	—	—
Hoagland's solution plus NaCl, 0.005M	158.9*	178.5*	93.9*	211.1*	—	—	—	—	—	—	—	—
Hoagland's solution but one-half of Mg from $MgCl_2$	—	—	—	—	368.0**	268.5	120.0*	162.0*	107.2	135.6	235.6	228.6*
Hoagland's solution plus Na_2SO_4, 0.001M	—	—	—	—	343.7*	274.5	—	—	—	—	—	—
Hoagland's solution plus Na_2SO_4, 0.002M	—	—	—	—	321.7	234.0	—	—	—	—	—	—
Hoagland's solution plus Na_2SO_4, 0.0025M	137.4	160.1	74.9	158.5	—	—	—	—	—	—	—	—
Solution with Na but low in SO_4	—	—	—	—	—	—	98.3	140.3	97.7	126.6	242.2	186.2
*Necessary for	25.0	34.7	15.9	47.1	75.2	79.4	18.7	24.5	No sig.	No. sig.	No sig.	54.6
**Significance	34.0	46.8	—	—	101.3	106.8	—	—				—

$Mg(NO_3)_2$, 0.001M; $Ca(NO_3)_2$, 0.004M; KNO_3, 0.005M, and Na_2SO_4, 0.001M. In experiment 5 the solutions were similar except no NaCl was added.

In experiments 1, 2, 3 and 5, three plants were grown in each 15 liter asphalt painted iron container with iron cover. In experiment 4, a like number was used in 2-liter Pyrex beakers with Pyrex covers.

Plants for experiment 1 were transferred to experimental solutions November 21, 1941. Chemicals equivalent to those in the initial experimental solution were added December 23. The beets were harvested January 24, 1942. The range of time for experiment 2 was from December 16, 1941 to February 4, 1942. Experiment 3 ran from February 7 to April 14, 1942. Solutions were changed March 26. Experiment 4 was started April 4 and terminated May 1, 1942. As previously stated it was carried out in 2-liter Pyrex beakers. Because of the small amount of solution available to the plants, the solutions were changed on April 14 and April 28. In addition chemicals equivalent to those in the initial solutions were added between each change on April 11 and on April 18. Experiment 5 was started on January 29, 1947, and was terminated on March 21 because it was no longer possible to maintain the low temperatures required in the 50 to 60 degrees F house. On March 11 chemicals equivalent to those used in initial solutions were added to the beets in the 70 to 80 degrees F house. Because of reduced growth due to low temperatures in the 50 to 60 degrees F house the proportion of chemicals added was reduced to one-half.

In all experiments K_2SiO_3 was used to supply 5 to 10 parts per million Si.

Results

As shown in Table I in experiment 1, adding KCl, 0.05M gave a significant increase in weight of beets at the 1 per cent level of significance. The same quantity of NaCl significantly increased the growth of beets at the 5 per cent level. Both increased the growth of tops at the 5 per cent level.

In experiment 2 the same additions increased the weight of both beets and tops at the 5 per cent level of significance but K_2SO_4, 0.025M also gave an increase in weight of beets that was slightly above that required to be significant at the 5 per cent level. In experiment 3 both additions of NaCl increased the yield of both beets and of tops at the 1 per cent level. Chlorine as $MgCl_2$ gave an equally significant increase in the weight of beets. Na_2SO_4, 0.001M gave an increase in the weight of the beets at the 5 per cent level. In experiment 4 the addition of NaCl increased the weight of tops and $MgCl_2$ increased the yield of both beets and tops at the 5 per cent level of significance. In experiment 5 $MgCl_2$ increased the weight of tops at the 5 per cent level.

Discussion

In these experiments in culture solutions, the addition of chlorides in general gave a much more consistent increase in the growth of table beets than did additions of soduim. It should not be inferred that similar results apply in soils. Following the work of Sayre and Shafer (3),

many New York growers have obtained increased yields of beets by using sodium chloride in addition to relatively heavy applications of fertilizer supplying considerable quantities of potassium chloride.

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The Performance of Palmetto, a New Downy Mildew-Resistant Cucumber Variety[1]

By W. C. Barnes, *Clemson College Truck Experiment Station, Charleston, S. C.*

In 1943, crosses were made between Puerto Rico 40, a short fruited, downy mildew resistant variety and Cubit, a long fruited, susceptible variety (1). In the sixth generation, the line 201A–3–7–2–1–2 was selected as having most of the features desired in a market type cucumber. This line has been carried through the eighth generation, using methods previously described (2), to insure a pure line and to check on performance under commercial conditions. It is hereby declared released to the commercial seed trade under the name of Palmetto.

Varietal Description

Palmetto vines are not greatly unlike those of Cubit. However, its leaves, as shown in Fig. 1, are deeply lobed in a manner that makes identification simple. The season of maturity is the same as Marketer, which usually is 3 to 5 days later than A and C or Cubit. Fruit shape, as shown in Figs. 1 and 2, more nearly approaches that of Cubit than that of any other variety, however, the fruit is slightly more pointed at the ends than is typical of Cubit fruits. Typical "fancy" fruits are 8 to 9 inches long or about the same as those of Cubit. Fruit color very closely approximates the excellent color of Cubit and Marketer and is superior to that of A and C. It is usually greatly superior in color to Burpee Hybrid and to the Puerto Rico varieties 37, 39, and 40. The seed cavity is small like that of Cubit and the color of the interior flesh is excellent. The flavor of Palmetto is good.

Spring Yield Tests

The yield tests reported in Table I indicate that in the spring Palmetto is probably not superior to the varieties now grown. This may be attributed to its lateness and to the fact that downy mildew usually does not become a serious factor until late in the season (4). At the Virginia Truck Experiment Station, Palmetto continued in production two weeks later than susceptible varieties in 1947, a season when mildew was much worse than normal. No mildew was present in Mississippi and no differences in performance were observed. Observations in South Carolina in 1946 and 1947 indicated this variety may remain in production 1 to 2 weeks longer than susceptible varieties. The Rhode Island and Illinois tests indicate poor performance of Pal-

[1]Technical contribution No. 151 from the South Carolina Agriculture Experiment Station.

The writer gratefully acknowledges the help of J. M. Jenkins, Jr., and C. N. Clayton, former members of the Truck Station staff. Two of the experiments reported were carried out by W. M. Epps, Associate Pathologist, in connection with fungicide studies. The following workers in other states have aided in testing the new variety: David G. A. Kelbert, Florida; W. S. Anderson, Mississippi; T. J. Nugent, Virginia; Henry M. Munger, New York; Desmond Dolan, Rhode Island; Charles Y. Arnold, Illinois; and Allen Trotter and Everett Clarke of Associated Seed Growers.

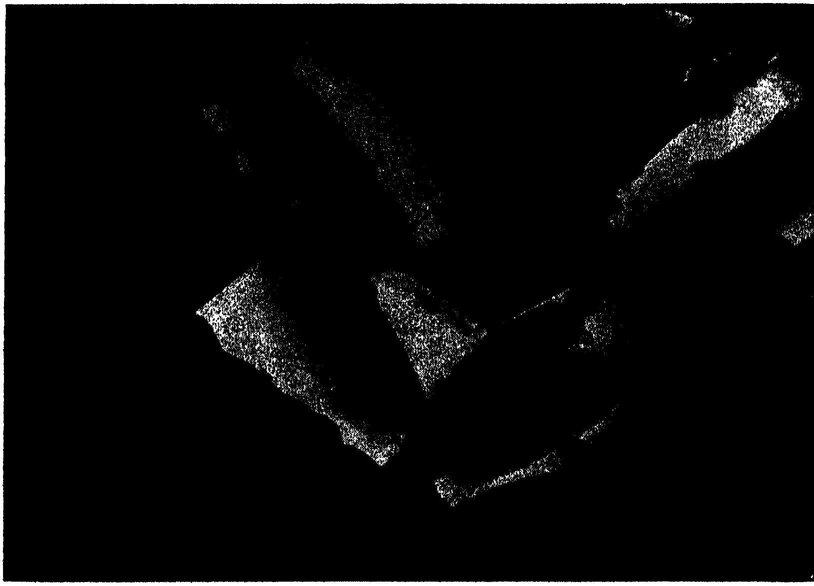

FIG. 1. The deeply lobed leaves and long cylindrical fruit are typical of the Palmetto cucumber.

FIG. 2. Typical "jumbo", "fancy", and "pickle" fruits of Palmetto. Note the small seed cavity of the cut fruit.

metto. In Rhode Island it is reported to have developed yellow off-color foliage early in the season. The application of additional nutrients failed to restore normal color. No definite reason for this is known, although a virus is suspected, as a similar performance of other lines has occurred in three instances during the 8 year history of the cucumber breeding project. This yellowing was not evident in the Connecticut seed plots. The cooperator in Illinois did not report any unusual growth that might explain the poor performance in that state.

TABLE I—YIELD OF CUCUMBER VARIETIES IN SPRING TRIALS

Variety	Yield (Bushels Per Acre)							
	S. C. 1946		Va. 1947		Miss. 1947		R. I. 1947,	Ill. 1947,
	Fancy	Total	Fancy	Total	Fancy	Total	Total	Total
Palmetto	252	330	157	196	49	74	57	257
Burpee Hybrid	303	370	259	319	—	—	102	695
Marketer	289	362	—	—	42	81	—	336
A and C	166	265	129	166	—	—	93	283
Cubit	176	257	116	144	—	—	—	346
Difference required for significance at 5 per cent point	60	74	75	89	N.S.	N.S.	11	—

FALL YIELD TESTS

In contrast with the spring crop performance, results reported in Table II indicate great differences in yield in favor of Palmetto when it is grown in the fall.

TABLE II—TOTAL MARKETABLE YIELD OF CUCUMBER VARIETIES IN FALL TRIALS

Variety	Yield (Bushels Per Acre)				
	1946		1947		
	Expt 1	Expt 2	Expt 1*	Expt 2	Expt 3
Palmetto	231	220	135	140	152
Burpee Hybrid	279	—	93	73	—
Marketer	138	229	35	6	31
Colorado or A and C	81	—	58	3	—
Difference required for significance at 5 per cent point	42	57	34	40	54

*Planted on grower's farm. All other tests were on Experiment Station Farm. Expt. 2, 1946, and Expt. 3, 1947, are average yields obtained in fungicide experiments conducted by W. M. Epps

The 1946 season was normal for control of downy mildew by the use of fungicides. In test 1, (Table II) the crop was dusted with a combination insecticide-fungicide dust at 5-day intervals as recommended by Clayton (3) and in a manner similar to commercial practice. In this test, Palmetto was decidedly superior to commercial varieties except Burpee Hybrid which possesses some resistance to mildew plus a lot of hybrid vigor. In test 2, which was a fungicide experiment conducted by Dr. W. M. Epps, Associate Plant Pathologist, an excellent job of dusting was performed. Since mildew was effectively controlled on Marketer, no differences in yield were obtained.

The 1947 fall season was outstanding for both total rainfall and fre-

quency of rainfall. This resulted in a severe epidemic of downy mildew in all experimental plots. Palmetto, under these conditions, surpassed the yield of susceptible varieties by differences of 2 to 23 times.

Preliminary tests in Florida and Texas gave results similar to those reported in the above paragraph.

RESISTANCE TO DISEASE

The chief reason for the differences in performance of the various varieties is evident in the per cent defoliation by downy mildew reported in Table III. While Palmetto is not immune to downy mildew, it is so highly resistant that it may be grown without benefit of fungicidal treatment in the fall crop where the disease is present during the entire season. It has been reported by various workers to be as resistant to mildew as Puerto Rico 39. Observations at Charleston indicate greater resistance will be evident when this variety is not grown adjacent to susceptible cucurbits. This is due to the fact that resistance is expressed not only as resistance to infection, but also failure of the fungus to sporulate readily even when infection is established. These facts are strikingly evident when resistant and susceptible varieties are grown in trials and the resistant plants become infected much more readily than they do when grown in isolated plots.

Observations at Milford, Connecticut, and Ithaca, New York, indicate Palmetto is susceptible to cucumber mosaic. Unfortunately, no information on relative susceptibility was obtained. One worker reported Palmetto somewhat tolerant to powdery mildew in the green house, but this observation has not been checked under commercial conditions.

TABLE III—ESTIMATES OF DEFOLIATION OF CUCUMBER VARIETIES BY DOWNY MILDEW*

Variety	Per Cent Defoliation		
	Virginia (Jul 18, 1947)	South Carolina (Oct 20, 1947)	
		Expt 1	Expt 2
Palmetto	44	25	25
Burpee Hybrid	75	60	80
Marketer	—	95	98
A and C	82	95	98
Cubit	91	97	99

*Similar results have been recorded at Charleston in other years and in Florida.

COMMERCIAL TRIALS

In the fall of 1947, seed of Palmetto and five other related resistant lines were planted on three farms in coastal South Carolina. The acreages planted and yields reported in Table IV were obtained from the growers' packing house records. The resistant and susceptible varieties were planted in one field and dusted alike with a combination insecticide-fungicide mixture at 5-day intervals as recommended by Clayton (3). Yield records were kept separately on the two lots, but no attempt was made to keep separate records in the six resistant lines.

The farm at Ritter was subjected to less rain and made a normal crop. The James Island crop was injured by rain and excessive dust

TABLE IV—TOTAL MARKETABLE YIELD OF PALMETTO AND MARKETER WHEN GROWN UNDER COMMERCIAL CONDITIONS

Farm Location	Palmetto*		Marketer	
	Acres	Bu Per Acre	Acres	Bu Per Acre
Ritter	17	324	33	36
Yonges Island	4	200†	21	50†
James Island	4½	182	15½	72

*Part of these acreages were breeding lines similar to Palmetto.
†Based on grower's observation rather than packinghouse records.

applications which helped control mildew on Marketer, thereby prolonging its harvest season, but caused injury which reduced the potential yield from the resistant lines. The Yonges Island crop was seeded later than is recommended and portions of both varieties were severely injured by nematodes.

Approximately half of the acreage in each of these tests was Palmetto and since it produced more than two or three of the other five lines, it is safe to conclude the performance reported in Table IV would have been as good and probably better had the entire plantings been Palmetto. Since Palmetto gave yields of three to nine times as much as Marketer under commercial conditions where the susceptible variety was immediately adjacent, it should give better results when it is used exclusively.

Marketer was 95 per cent defoliated in the Ritter planting on October 14, whereas Palmetto was only 10 per cent defoliated. Marketer was harvested only twice while Palmetto continued in production from September 22 to November 5. In this planting the average farm value of Palmetto was well above $1,000 per acre, whereas Marketer barely paid expenses of production.

SUMMARY

The introduction of the downy mildew resistant variety, Palmetto, will remove the greatest hazard in fall cucumber production in the southeastern states. Downy mildew resistant varieties previously introduced have not been acceptable because of poor fruit color, shape, and so on. Limited tests have not revealed any unfavorable market reaction to fruit length, shape, color, or carrying qualities of Palmetto. At this time it is not recommended as a spring crop variety, although further tests may reveal a place for its use. Furthermore, it may be limited to the South as northern trials have not been encouraging. A sister line of Palmetto that should be ready for release next year should fill the need of an early resistant variety.

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The Soluble Solids Content of Cantaloupes As Affected by the Use of Certain Fungicides in 1947[1]

By E. M. RAHN and J. W. HEUBERGER, *Delaware Agricultural Experiment Station, Newark, Del.*

THE stability of the cantaloupe industry depends upon the production of high quality melons. In an attempt to aid growers in producing melons of higher quality, research has been conducted by the Delaware Agricultural Experiment Station on the effect of fertilizers and fungicides on quality. The results with fertilizers have been inconclusive to date, but the results from the use of fungicides in 1947 were quite striking.

PROCEDURE

Fungicide treatments consisted of single row plots, 150 feet long, and replicated four times in a randomized-block arrangement. Fungicides were applied July 1, 8, 15, 22, 29, August 4, and 11. Sprays were applied with a power sprayer (five nozzles per row) at the rate of 75 to 100 gallons per acre at the first application, the rate increasing until 150 to 200 gallons were applied on full-grown plants. Dusts were applied at a 20- to 30-pound rate per acre at the first application and increased to 40 to 50 pounds per acre on full-grown plants.

The readings of a Zeiss hand refractometer were used as an index of quality. According to Currence and Larson (1) and Hartman and Gaylord (2), refractometer readings of cantaloupe juice and quality as rated by taste are closely correlated. Currence and Larson (1) state that a single observation of cantaloupe quality by the use of a hand refractometer has a standard error of estimate approximately equal to the standard error of the mean of six to eight tasting estimates. The Zeiss hand refractometer records directly as percentage of sucrose but the readings would be labeled more correctly as percentage of total soluble solids. The juice used for testing was taken from the flesh of ripe marketable melons about midway between the ends. Ten melons were tested for each sampling.

Downy mildew disease appeared on July 17 and rapidly became destructive because of favorable moisture and temperature conditions that prevailed until July 27. After this date, the weather turned hot and dry and remained so until the end of the experiment. Thus, the harvesting season was short, the dates of the first and last picking being August 4 and August 19, respectively. Downy mildew ceased development after August 1. Disease ratings on each plot were made by three persons according to the following standards:

0—No disease
1—Trace of spots
2—Several spots per leaf
3—Many spots per leaf
4—Ditto plus leaf curling
5—Severe leaf curling
6—Severe leaf curling plus some dying
7—25 per cent leaves dead
8—50 per cent leaves dead
9—75 per cent leaves dead
10—Completely dead

[1]Published as Miscellaneous Paper No. 42 with the approval of the Director of the Delaware Agricultural Experiment Station. Contribution (No. 12) of the Department of Horticulture and Contribution (No. 6) of the Department of Plant Pathology. Dec. 2, 1947.

Results and Discussion

Complete data are presented in Table I on the fungicide treatments and their effect on downy mildew disease control, yield, percentage of crop harvested at various dates, and percentage of soluble solids.

The data on disease control show that the untreated plots were completely dead on August 12, whereas all the fungicide treatments gave good control. As regards quality or percentage of soluble solids, the data show that on no sampling date did fruits from the untreated plots average 8 per cent soluble solids, as required by a Delaware law. On the other hand, nearly 70 per cent of the total crop was harvested on the fungicide-treated plots before the soluble-solids content dropped to approximately 8 per cent. On the whole, the same fungicide com-

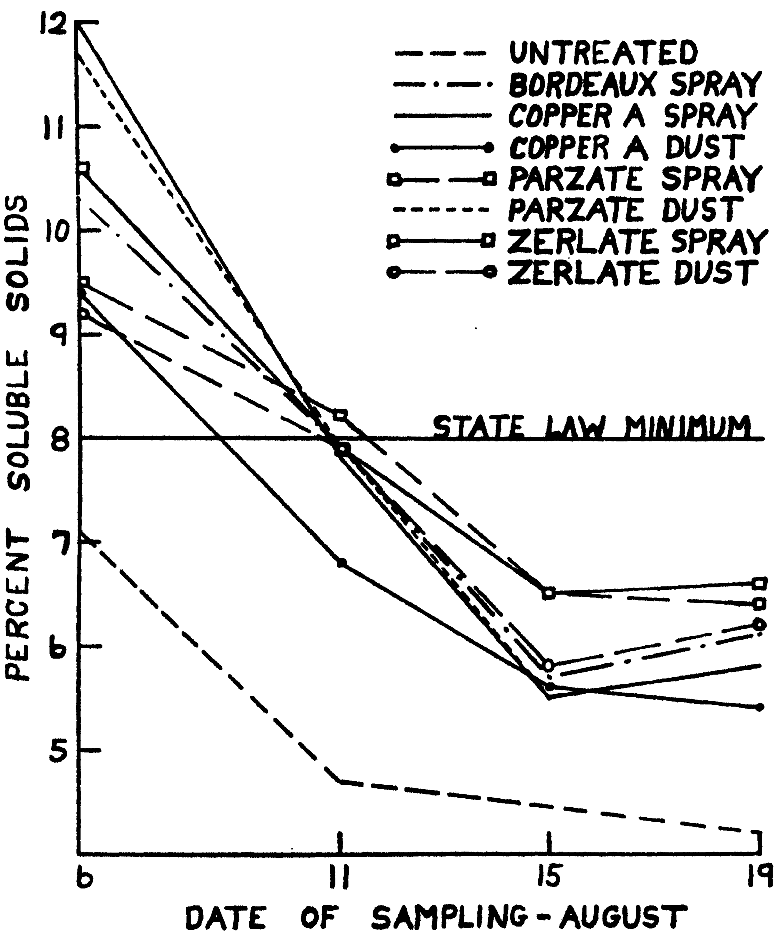

FIG. 1. Percentage of soluble solids of cantaloupes taken from treated and untreated plots on four dates during the 1947 season.

TABLE I—EFFECT OF FUNGICIDES ON THE CONTROL OF DOWNY MILDEW DISEASE, THE SOLUBLE-SOLIDS CONTENT, AND YIELD OF CANTALOUPES AT GEORGETOWN, DELAWARE (1947)

Treatment	Concentration (Lbs Gals)	Disease Rating on Aug 12	Dates of Sampling: Aug 6		Aug 11		Aug 15		Aug 19		Marketable Yield Per Acre	
			Per Cent Soluble Solids	Per Cent Harvested	Per Cent Soluble Solids	Per Cent Harvested	Per Cent Soluble Solids	Per Cent Harvested	Per Cent Soluble Solids	Per Cent Harvested	No.	Weight (Tons)
1. Untreated	—	10.0	7.1	28	4.7	94	—	100	4.2*	100	7,792	12.6
2. Bordeaux Spray	6-3-100	2.5	10.3	6	7.9	69	5.7	92	6.1	100	8,034	12.9
3. Copper Compound A Spray	3⅓-100	3.8	12.0	9	7.8	67	5.5	93	5.8	100	7,938	13.0
4. Copper Compound A Dust (10 per cent)	—	5.3	9.4	6	6.8	69	5.6	91	5.4	100	9,051	15.1
5. Zerlate Spray	2-100	3.5	10.6	11	7.9	67	6.5	93	6.6	100	9,293	14.3
6. Zerlate Dust (8 per cent)	—	4.0	9.2	11	7.9	74	5.8	95	6.2	100	10,019	15.9
7. Parzate Spray	2-100	2.8	9.5	9	8.2	72	6.5	92	6.4	100	8,760	14.1
8. Parzate Dust (8 per cent)	—	5.3	11.7	6	7.9	70	5.5	95	5.8	100	8,954	14.9
Least significant difference (5 per dent level)		—	1.7	—	1.6	—	1.3	—	1.0	—	1,152	2.0

*Culls were sampled because no marketable fruit were harvested.

pound when used as a spray gave a higher soluble-solids content than when used as a dust; the reverse was true for yield.

SUMMARY

The fungicides used, by controlling downy mildew disease, increased yield and quality. The increase in percentage of soluble solids over that for the untreated plots was statistically significant in all cases while the increase in yield was statistically significant only for the dust treatments on the basis of both number and weight. On the basis of number of melons, the use of Zerlate spray too resulted in a statistically significant increase in yield.

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Susceptibility of Cucurbitaceae to Squash Borer[1]

By W. D. WHITCOMB and W. J. GARLAND, *Waltham Field Station, Massachusetts Agricultural Experiment Station, Waltham, Mass.*

DURING the past 20 years, conflicting statements have occurred frequently regarding injury to cucurbits by the squash borer. Thompson (4) wrote, "while this insect (squash vine borer) attacks all cucurbits, it prefers squash and pumpkin". Jones and Rosa (3) said, "this insect does not attack early varieties but is one of the chief enemies of winter squash". Gilbert and Popenoe (2) report, "after cucumbers and melons have made good growth, they are sometimes attacked by the squash vine borer which, however, is much more destructive to pumpkins and squashes, especially the Hubbard and summer bush squashes".

These inconsistencies led to studies to determine the relative susceptibility to this insect of 19 varieties embracing six species of *Cucurbitaceae*. The work was done at the Waltham Field Station of the Massachusetts Agricultural Experiment Station where the natural infestation in Hubbard squash had varied from 3 to 15 borers per vine for the past 12 years.

The seed was planted in hills 12 by 12 feet and each hill was thinned to four plants. The different varieties were grown in adjacent rows and in some cases in duplicate plantings. Records were taken by pulling and splitting the stem for 4 feet from the root and counting the number of borers and the number of tunnels from which the borers had emerged. It is known that some partly grown borers leave a tunnel and make a second one, but observations indicate that this happens very seldom and should not influence the records significantly. Roots were pulled and the stems examined during the last week in August at which time the borer infestation was complete.

It is interesting to note that those varieties, such as Blue Hubbard and Warren Turban, which produce strong secondary roots at the nodes wilted only slightly for a few hours after the roots were cut off and continued growth to produce an apparently normal crop.

No actual comparisons of yield of squash cut at the roots, as described above, were made with vines which were not cut. However, in 1941 and 1942 Blue Hubbard vines in the experimental plats which were cut in late August yielded at the rate of 20,073 pounds or about 10 tons per acre on plantings of 20,000 square feet. The average yield of winter squash in this area was reported by the Massachusetts Department of Agriculture in 1941 (5) as 7.5 tons per acre, and by the Essex County (Massachusetts) Extension Service (1) in 1943 as 6.5 tons per acre.

As shown in Table I, the infestation was greatest in *Cuburbita maxima* and intermediate in *C. pepo*. In the experimental plantings consisting of 60 to 120 vines of each variety, no borers were observed in

[1]Contribution No. 651 Massachusetts Agricultural Experiment Station.
The assistance of W. E. Tomlinson, Jr., formerly Laboratory Assistant, is hereby acknowledged.

TABLE I—SUSCEPTIBILITY OF SPECIES OF CUCURBITACEAE TO SQUASH BORER (WALTHAM, MASSACHUSETTS)

Species of Cucurbitaceae	Number of Varieties			Per Cent of Plants Infested			Average Number of Borers and Borer Tunnels Per Plant			Species Average
	1944	1945	1946	1944	1945	1946	1944	1945	1946	
Cucurbita maxima	3	4	3	96.67	100.00	95.00	3.31	5.45	2.88	4.04
Cucurbita pepo	6	6	3	76.67	94.17	86.67	2.23	3.47	1.70	2.62
Cucurbita moschata	1	6	3	None	None	None	None	None	None	None
Cucumis sativus	1	1	1	None	None	None	None	None	None	None
Cucumis melo	1	1	1	None	None	None	None	None	None	None
Citrullus vulgaris	1	1	1	None	None	None	None	None	None	None

TABLE II—SUSCEPTIBILITY OF VARIETIES OF CUCURBITACEAE TO SQUASH BORER

Variety	Average Number of Borers and Borer Tunnels Per Plant			Variety Average
	1944	1945	1946	
		Cucurbita Maxima		
Warren Turban	3.10	6.85	2.90	4.28
Blue Hubbard	3.65	4.35	3.30	3.77
Buttercup	3.20	5.05	2.45	3.57
Bush Buttercup	—	5.55	—	5.55
		Cucurbita Pepo		
Table Queen	1.95	4.45	2.70	3.03
White Bush Scallop	2.30	3.55	—	2.92
Early Prolific (Summer squash)	3.65	3.70	1.05	2.80
Gourd (Ornamental mixed)	1.20	3.40	—	2.30
Small Sugar (Pumpkin)	2.45	2.90	1.35	2.23
Cocozelle (Summer squash)	1.85	2.53	—	2.19
		Cucurbita Moschata		
Butternut	None	None	None	None
Large Cheese	—	None	None	None
Tennessee Sweet Potato	—	None	None	None
Golden Cushaw	—	None	—	None
Longfellow	—	None	—	None
Alagold	—	None	—	None

cantaloupe, watermelon, cucumber, or in any varieties of *C. moschata*. In 1945, however, 3 of the 20 cucumber plants examined showed tunnels resembling those made by the squash borer. No insect was found in these tunnels and similar injuries were not observed in other years. In 1947 squash borer larvae were twice found in the stem of a Butternut vine growing in a field of several hundred plants. Although the complete immunity found in the limited plantings of this experiment might not persist in a large block grown in an infested area, it is evident that a heavy infestation of squash borer will not occur on the resistant varieties.

The degree of infestation in *Cucurbita maxima* and *C. pepo* appears to be influenced considerably by the size and vigor of the stems. The larger, rapidly growing stems of *C. maxima* varieties are obviously attractive to moths during oviposition, and there appears to be a greater survival of larvae than in the smaller, harder stems of *C. pepo*.

Among the varieties of *Cucurbita maxima*, these observations showed few significant differences. Although Warren Turban had the highest average infestation, the number of borers in Blue Hubbard

was greater in 2 of the 3 years under observation than in Warren Turban. The greatest number of borers per plant in the entire experiment was recorded in 1945 when 14 worms were found in one Warren Turban stem. The maximum number in Blue Hubbard was 12, and the same number was also found in Early Prolific summer squash.

In the *Cucurbita pepo* group, Table Queen, Scallop, and Early Prolific averaged significantly heavier infestations than gourds, Sugar Pumpkin, and Cocozelle but this difference was not maintained each year. It is significant, however, that with a few exceptions the greatest infestation in varieties of *C. pepo* was less than the smallest infestation in *C. maxima*.

In these experiments, borer injury was much less serious to the growth of vines and maturity of the crop than is generally believed. On Blue Hubbard, Warren Turban, and other varieties which grow strong secondary roots, the crop is affected seriously only when severe borer injury occurs early in the season, or on late plantings before the secondary roots have grown.

On all bush varieties and others which do not produce secondary roots, one or two borers per plant have surprisingly little harmful effect on growth. Thick stalked plants like Early Prolific Straightneck have harbored 10 and 12 borers while producing an excellent yield of good quality squash. This resistance to serious injury is very important since the usual control measures with insecticides seldom reduce a moderate or heavy infestation below one or two borers per plant.

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The Effect of Rotenone, Commercial, and Aerosol Grade DDT Dusts on the Total Yield, Grade, and Maturity of Seven Cucurbit Varieties[1]

By E. K. ALBAN and V. E. KEIRNS, *Ohio State University, Columbus, Ohio*

MANY investigators have reported during the last three years that practically all of the cucurbit varieties are damaged when sprayed or dusted with the commercial grade DDT. However, DDT is one of the most effective insecticides available in controlling the four major cucurbit insects, the striped and twelve spotted cucumber beetles, the squash bug, and the squash vine borer.

During the summer of 1946, the Department of Horticulture of the Ohio State University tested 42 cucurbit varieties to determine their relative resistance to DDT sprays (1). All of the varieties revealed some damage, but 11 varieties recovered sufficiently to produce a fair crop. The major fact noted, however, was the almost complete absence of cucurbit insects even on adjacent plots not sprayed with DDT.

In an effort to determine the plant toxic fraction of commercial DDT, Mr. Carl Condron, Graduate Assistant in the Department of Horticulture, Ohio State University, worked with Mr. E. D. Witman, Department of Agricultural Chemistry, separated four fractions from a commercial sample. These fractions were sprayed on melon plants in the greenhouse and it was found that a sludgy, oily fraction caused the most damage to the plants. Since the aerosol grade DDT has this fraction removed in processing, a dust was prepared which contained 5 per cent of this aerosol or technical grade DDT. This dust was not available for field application until the middle of August, 1946. One variety, White Bush Scallop, which had been shown to be particularly susceptible to DDT injury, was planted and dusted regularly until frost destroyed the plants. None of these plants exhibited any characteristic DDT injury, but since it was late in the season and rather cool, no conclusive information was obtained.

In 1947 a more comprehensive study was planned to determine the relative efficiency of the standard dusting treatment of 0.75 per cent rotenone as compared to the commercial DDT (5 per cent) and the aerosol or technical grade DDT (5 per cent) on seven cucurbit varieties. The following varieties were planted in the field on June 5, 1947; one cucumber, Woodruff's Ace; two summer squash, White Bush Scallop, and Table Queen; two pumpkin, Small Sugar and Connecticut Field; and two muskmelon, Delicious and Pride of Wisconsin. A randomized block with seven varieties in each plot and three replicated plots for each dust treatment were established. Sufficient seed was planted to assure an adequate stand of plants and on July 2, the planting was thinned to three plants per hill. The spacing in the row was 5 feet between hills and between rows the spacing was 6 feet.

[1]The Sherwin-Williams Company furnished a grant for carrying out this work and supplied the aerosol grade DDT.

Accepted cultural practices were used in growing the crops except as noted.

All dust treatments were begun as soon as the first seedlings emerged (June 10) and were maintained as needed throughout the growing season. A total of 16 different applications were made at the average rate of 25 pounds of dust per acre. In addition seven copper dusts (4 per cent) were applied after the plants had begun to vine.

Frequent observations were made throughout the growing season to determine the relative tolerance of the plants to the various dust treatments (insecticides). Table Queen, Small Sugar, and White Bush Scallop were damaged immediately with the first few dusts of commercial DDT, and this injury was apparent the rest of the season. Many of these plants died and the remaining plants were stunted and yellowed. None of these varieties dusted with the aerosol DDT or the rotenone exhibited any of the above damage. Woodruff's Ace, Delicious, and Pride of Wisconsin did not reveal any serious stunting or yellowing following application of either grade DDT dust. Late in the season, following several copper dusts, there was some slight marginal chlorosis of all varieties in all plots, which indicated probable copper injury. The foliage damage noted with all varieties dusted with commercial DDT followed the same pattern observed in previous studies with these varieties. Rotenone and the aerosol grade DDT dusts did not cause any easily recognized damage with any of the varieties.

Yield data were obtained as the crops reached harvestable maturity. However, due to relatively low temperatures early in the season, the muskmelon varieties were late in maturing and a frost made it necessary to remove all marketable size melons from the vines, though they were not ripe on the last harvest date, October 2. In all other instances, the fruits were harvested at the normal harvesting periods, and with the exception of cucumbers, only the marketable fruit were harvested. There were relatively few non-marketable fruits with any of the other varieties and these were not associated with any specific treatment.

Results and Discussion

Cucumber:—There was a minimum visual damage to the variety Woodruff's Ace with either of the DDT dusts. This was also reflected in the yield data (Table I) since both DDT treated plots produced more fruit than the rotenone treated plots. The effect of the various dust treatments on maturity was slight and no evidence was obtained that DDT dusts lowered the grade or marketability of the crop. Based on the results obtained with this variety it would seem very worth while to use the aerosol DDT to control the twelve spotted and striped cucumber beetle. One of the contributing factors to the higher yield with the DDT dusts appeared to be the reduction of bacterial wilt in the DDT treated plots. Those plants treated with rotenone had a rather high percentage of bacterial wilt and the foliage went down much earlier than was true with DDT treated plants.

Muskmelon:—There was some evidence of slight dwarfing early in the season with both varieties of melons, Delicious and Pride of Wis-

TABLE I—THE EFFECT OF ROTENONE, COMMERCIAL, AND AEROSOL GRADE DDT DUSTS ON THE TOTAL YIELD OF WOODRUFF'S ACE (CUCUMBER), DELICIOUS AND PRIDE OF WISCONSIN (MUSKMELONS). TOTAL FROM THREE REPLICATED PLOTS — 150 FEET OF ROW*

Treatment	Variety		
	Woodruff's Ace	Delicious	Pride of Wisconsin
Rotenone (0.75 per cent)			
Total number	266	85	50
Total weight	159.75	304.00	184.00
Commercial DDT (5 per cent)			
Total number	340	120	60
Total weight	164.75	509.00	231.50
Aerosol DDT (5 per cent)			
Total number	481	170	62
Total weight	297.25	712.50	257.50
Statistical significant difference	N.S.	163.20 (5 per cent level)	N.S.

*All fruits were harvested at marketable maturity with the exception of the last harvest of Delicious and Pride of Wisconsin. In this instance, all fruits were harvested on basis of marketable size since a killing frost prevented further development. There was no significant difference due to treatments in relation to grade or maturity of the harvested fruits. There was a slight tendency for both DDT dusts to retard maturity of the muskmelons, but there was no statistically significant difference.

consin, which had been dusted with the commercial DDT. However, as the season progressed there were no outstanding visual symptoms of DDT toxicity with either dust and the plants in all treatments were of about equal size and appearance.

No very satisfactory explanation was obtained for the higher yield (Table I) of fruit from the DDT treated plants as compared with rotenone treated plants. However, the foliage of aersol DDT treated plants was very luxuriant, particularly toward the end of the season.

While analysis of maturity data were not statistically significant, it was apparent that a trend toward delayed maturity was exhibited in both of the DDT treated plots as compared with the rotenone plots.

Summer Squash:—The two varieties of squash (White Bush Scallop and Table Queen) chosen for the study this year were used because of our previous knowledge that they were susceptible to DDT injury. The 5 per cent commercial DDT dust practically eliminated these varieties in our field tests this past year. However, the 5 per cent aerosol DDT dust, while it did lower the yield somewhat, caused a minimum visible damage to the foliage of these very susceptible squash varieties. There was no indication that the maturity or grade of the fruit was affected materially (Table II). Based on yield, Table Queen was more resistant to aerosol DDT dust than was White Bush Scallop.

During 1946 it was noted that the squash-bug and vine-borer were not important even in adjacent plots not sprayed with DDT and the same thing seems evident in our studies this year. None of the cucurbits in this experiment were infested with either pest. On a plot about 400 feet away, where 25 other squash and pumpkin varieties were growing (treated with rotenone), both of these insects were present. Two aerosol DDT dusts over this affected area in August eliminated both insects and caused no visual damage to the plants. While it is apparent that the aerosol DDT may damage some of the squash and pumpkin varieties it would seem worth while to use it when the squash-bug or vine-borer was a major problem.

Pumpkin:—The Small Sugar variety of pumpkin was severely damaged with the commercial DDT but the aerosol DDT did not cause

TABLE II—THE EFFECT OF ROTENONE, COMMERCIAL, AND AEROSOL GRADE DDT DUSTS ON THE TOTAL YIELD OF WHITE BUSH SCALLOP, TABLE QUEEN, SMALL SUGAR, AND CONNECTICUT FIELD. TOTAL FROM THREE REPLICATED PLOTS — 150 FEET OF ROW

Treatment	Variety			
	White Bush Scallop*	Small Sugar†	Table Queen†	Connecticut Field†
Rotenone (0.75 per cent)				
Total number	709	303	534	116
Total weight	1,323.00	1,275.00	607.00	1,620.00
Commercial DDT (5 per cent)				
Total number	37	24	6	74
Total weight	64.00	119.00	7.00	1,240.00
Aerosol DDT (5 per cent)				
Total number.	600	245	518	113
Total weight	1,005.00	1,925.00	589.00	1,840.00
Statistical significant difference	189.30 1 per cent level	352.80 5 per cent level	163.80 1 per cent level	N.S.

*Three harvest dates—no significant difference between treatments in relation to maturity or grade of harvested fruits.

†One harvest date—no significant difference between treatments in relation to maturity or grade of harvested fruits.

any visual toxic symptoms. Connecticut Field pumpkin was damaged slightly (chlorosis of a few leaves) with commercial DDT, but there was no damage with the aerosol DDT. In Table II, the yield data for each of the treatments and for each of the varieties follows generally the observations made on the plants as mentioned above.

SUMMARY

Commercial and aerosol grade DDT, and Rotenone dusts were applied on seven cucurbit varieties during the growing season to determine the effect of these materials on the total yield, maturity, and grade of the harvested fruits. The varieties used included Table Queen, White Bush Scallop, Small Sugar, Connecticut Field, Pride of Wisconsin, Delicious, and Woodruff's Ace.

The commercial DDT dust treatments on Table Queen, Small Sugar, and White Bush Scallop, resulted in a statistically significant reduction in yield as compared with the Rotenone treated plants. The muskmelon, Delicious, was the only variety of the seven cucurbits tested, where the commercial DDT treatment resulted in a statistically significant increase in yield over the Rotenone Treatment.

In only one instance did the aerosol DDT dust result in a statistically significant reduction in yield as compared with Rotenone and this was with the variety White Bush Scallop. With the six remaining varieties the aerosol grade DDT plants produced as large a total yield, and in the case of Delicious, and Small Sugar, a statistically significant increase in yield as compared with the Rotenone.

Neither the commercial nor the aerosol DDT treatments caused any significant change in days to maturity or in per cent of marketable fruits as compared with the Rotenone.

The aerosol grade DDT compared favorably with Rotenone as an

insecticide on the above varieties. The more effective insecticidal value of the aerosol DDT would indicate that where cucurbit insects are a major problem, this dust might be used in preference to Rotenone.

The commercial grade of DDT available at the present time should not be used on cucurbits, especially if the aerosol grade DDT is available. While a few varieties of cucurbits are fairly tolerant of commercial DDT, most varieties may be seriously damaged.

Literature Cited

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Using Hormone Sprays to Facilitate Bolting and Seed Production of Hard-Headed Lettuce Varieties[1]

By DeLance F. Franklin, *University of Idaho, Parma Branch Station, Parma, Idaho*

In the production of lettuce seed from hard-headed varieties, such as Imperials 847 and 152 and N. Y. 515, it usually has been necessary to slash or break open the heads to effect the release of the seedstalk. This operation adds appreciably to the cost of production.

With the advent of Great Lakes and Cornell 456, two new nearly non-bolting varieties, the problem has been increased many fold because the heads form so tightly, even after slashing, that the seedstalk cannot readily escape. Indeed, the problem in the case of these varieties is so serious that it seems doubtful whether the non-bolting character responsible for their popularity can be commercially maintained, because each year seed is produced largely from those plants having the greatest propensity for bolting.

In an attempt to obviate the necessity for slashing the heads of all hard-headed varieties, and to make it possible to produce economic yields of genetically-acceptable seed from the Great Lakes and Cornell 456 varieties, experiments were set up wherein various growth regulators were used in an attempt, by inducing leaf epinasty, to prevent the usual compression of the leaves or to cause headed plants to become less compressed, and thus permit the release of the seedstalk.

The 1946 Experiment

In this experiment the following materials and concentrations were applied as sprays to Great Lakes lettuce which had been planted April 12: (a) α-naphthalene acetate at 100, 150, 200, and 250 ppm; (b) indolebutyric acid at 150, 200, 250, and 300 ppm; (c) the ammonium salt of 2,4-dichlorophenoxy acetic acid at 50, 75, 100, and 150 ppm; (d) p-chlorophenoxy acetic acid at 100, 150, 200, and 250 ppm; (e) methyl α-naphthalene acetate at 50, 75, 100, and 150 ppm; and (f) ethyl 2,4-dichlorophenoxy acetic acid at 50, 75, 100, and 150 ppm. Each treatment was applied by use of a knapsack sprayer to a separate plot on each of three different dates, as follows: (a) May 18, when the plants were in a very small rosette stage and possessed of five or six true leaves; (b) June 2, when the plants were in a large rosette stage with some leaves beginning to enfold in the initiation of heads; and (c) June 29, when the plants were headed as for commercial packing. Each plot consisted of a single row 40 feet long with plants spaced 12 to 15 inches within the row.

Results

The results of this experiment differed both with the hormone used and the date of application.

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In general, it appeared that the materials which produced any observable alteration in plant conformation were most active and most lethal when applied on May 18, when the plants possessed only five or six true leaves. Conversely, plants sprayed with the same materials at the same concentrations on June 29th when fully headed were affected little or none at all. Within the limits of this experiment, the optimum date for application of these sprays appeared to be on June 2, when the plants were in the large rosette stage with the leaves of some plants just starting to enfold.

In all cases where the 2,4–dichlorophenoxy compounds were used on the first two dates, the desired epinasty of the leaves (Fig. 1, left)

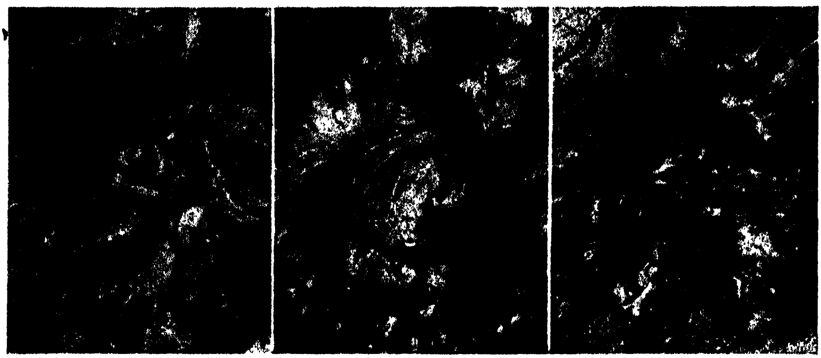

Fig. 1. Typical conformation resulting from spraying lettuce plants of the Great Lake variety with certain growth regulators. Left, showing epinasty of outer leaves and failure to head following treatment with the ammonium salt of 2,4–dichlorophenoxy acetic acid; center, untreated check; and right, showing epinasty of outer leaves and failure to head resulting from treatment with p-chlorophenoxy acetic acid.

was induced, but even at the lowest concentrations caused the death of many plants. In a few instances the survivors tardily initiated naked seedstalks, but failed to blossom and set seed. Where the 2,4–dichlorophenoxy treatments resulted in the death of the plants, death was preceded by enlargements of the secondary roots similar in appearance to that resulting from nematode infection.

α-naphthalene acetate, methyl-α-naphthalene acetate, and indolebutyric acid induced very little epinasty and did not otherwise affect seedstalk development in any way at the concentrations used.

Where p-chlorophenoxy acetic acid at 100 ppm was used, heading was almost entirely prevented (Fig. 1, right) and seedstalks, slightly dwarfed but otherwise normal, appeared and bore viable seed.

The 1947 Experiment

This study was modified in 1947 along the lines suggested by the results of 1946. One additional hormone, β-naphthoxy acetic acid at 20, 30, 40, and 100 ppm, was tried; and a mechanical treatment, consisting of the excision of the apical bud, was added as a check in addi-

tion to the regular untreated check plot. The concentrations used in the other treatments were as follows: ammonium salt of 2,4–dichlorophenoxy acetic acid at 10, 20, 30, and 40 ppm; methyl α-naphthalene acetate at 200, 250, 300, and 350 ppm; and α-naphthalene acetic acid at 50, 75, 100, and 125 ppm. These materials were sprayed onto different plots of Great Lakes lettuce which had been planted March 6. A single spray of each material and concentration was applied on the following dates: (a) May 12, when the plants were in a large rosette stage, but before any enfolding of the leaves was manifest on any plants; and (b) May 22, when the plants were in a large rosette stage with enfolding of the leaves started on many plants. Plot sizes were essentially the same as in 1946.

Results

As in 1946, the most desirable stage for applying the sprays in 1947 appeared to be when the plants were in the large rosette stage, with enfolding of the leaves just starting, except where β-naphthoxy acetic acid and α-naphthalene acetate were used, where the earlier date was better. Generally where favorable responses were obtained with earlier applications, however, the effects were largely outgrown before seedstalks emerged.

Fig. 2. Cross-sections of Great Lakes lettuce plants. Left, sprayed with ammonium salt of 2,4–dichlorophenoxy acetic acid at 20 ppm; right, unsprayed check.

With the exception of α-naphthalene acetic acid, all materials used provoked some degree of epinasty at one or more concentrations, but this effect was not prolonged enough in most cases to permit release of the seedstalk. P-chlorophenoxy acetic acid at both dates and at all concentrations used produced early epinasty and intense rigidity of the leaves, but did not effect the satisfactory release of the seedstalks that it did in 1946. This may have been due to the earlier planting date used in 1947 and the consequent cooler temperature encountered, or it might have been due to the fact that the nutrient level, especially of nitrogen, of the soil used in 1947 was considerably higher than that used for the 1946 experiment.

The ammonium salt of 2,4–dichlorophenoxy acetic acid at 20 ppm, however, produced the best results achieved to date, with approximately 90 per cent of the individuals receiving this treatment developing seedstalks in the manner indicated in Fig. 2, left. Although slightly stunted as a result of the treatment, otherwise the seedstalks developed normally and appeared to produce quantities of viable seed approaching the yield of the more prolific-seeding varieties.

Summary and Conclusions

In attempts to produce leaf epinasty and thus circumvent the expensive necessity of slashing or breaking open hard-headed lettuce varieties in order to effect the release of the seedstalk and the production of genetically-acceptable seed, various hormone sprays were applied to Great Lakes lettuce plants in 1946 and 1947. In all, seven different growth regulating compounds were used at four or more different concentrations and at two or more stages of plant development.

Although most of the materials produced the desired epinasty at one or more of the concentrations used, in many cases release of the seedstalk was not affected, either because the effect of the treatment was too quickly spent or because the concentrations were so strong as to cause either death of the plant or inhibition of seedstalk development. Some treatments, however, produced epinasty, seedstalk release and seed in a manner approaching the desired results.

Of the treatments used to date, the ammonium salt of 2,4-dichlorophenoxy acetic acid at 20 ppm, applied when the plants were in a large rosette stage with enfolding of the leaves just starting, was the most effective and cheapest. It is possible, however, that a concentration of 15 ppm, as yet untested, may prove to be more satisfactory.

Before this means of releasing the seedstalk can be used commercially, it will be necessary to determine considerably more than is now known respecting the relationship between planting date, soil fertility, and the effectiveness of these sprays. Also, more attention needs to be directed towards rates of application. Such studies are planned for 1948.

The Effect of Varying Amounts of Irrigation on the Composition of Two Varieties of Snap Beans

By Byron E. Janes, *University of Florida Agricultural Experiment Station, Gainesville, Fla.*

During the past decade there has been much interest in determining the factors which influence the composition of vegetables. It has been shown by several workers (1, 2, 9, 12, 13, 15) that factors associated with the climatological environment of a particular location or season exert a greater influence on the organic composition of crops than amount or kind of fertilizer, the soil type or the variety. One of the factors which is influenced considerably by climatic environment from one location or one season to another is the soil moisture. The work of the Southern Cooperative Group (9, 10, 12, 15) has shown that the amount of rainfall and irrigation does influence the composition of a vegetable, especially the organic constituents. This group found a positive correlation between ascorbic acid content in turnip greens and rainfall. There was little or no correlation between rainfall or irrigation and iron, calcium or phosphorus content. Lee and Sayre (5) have shown that tomatoes grown with restricted soil moisture have a higher total acid content than those grown with abundant moisture. Brooks and MacGillivray (2) reported that the dry matter of tomato fruit varies inversely with the percentage of soil moisture. McMurtrey *et al* (6) showed that there was a higher percentage of potash in leaves of tobacco plants grown under irrigation than when grown without irrigation, while nitrogen was higher in the leaves of tobacco plants grown under relatively dry conditions.

For several years the Horticultural Department of the Florida Agricultural Experiment Station has been studying the factors affecting the composition of vegetables, as well as the effect of irrigation on the yield of vegetables. The first study indicated that the amount of soil moisture might be one of the factors which influenced the composition of crops. The spring of 1947 was extremely dry, resulting in a marked response of the beans grown on the irrigation plots to varying amounts of irrigation. This effect of irrigation resulted in an excellent supply of material to study the effects of soil moisture on the composition.

Materials and Methods

Two varieties of snap beans, Logan and Black Valentine, were grown under four irrigation treatments; no irrigation, a light irrigation, a heavy irrigation and the same amount of water as the heavy irrigation split into two applications. These treatments were randomized in a latin square. The method and time of irrigation and other cultural practices, as well as the yields, are given by Nettles (8) in his discussion of the effects of irrigation on yields. The growing season, especially the latter part, was extremely dry, resulting in a marked response to the irrigation treatments as was shown by difference in yield and appearance. The yields varied from an average of 24 bushels

per acre for the non-irrigated plots to an average of 291.2 bushels per acre for the split application plots.

A sample of approximately 2 pounds from each plot was taken to the laboratory as soon as harvested and a sub-sample of 500 grams weighed out. The number of beans in the sub-sample were counted. The beans were washed in tap water and the excess water removed by centrifuging in a small basket centrifuge for 1 or 2 minutes at 1500 to 2000 revolutions per minute. The washed beans were chopped into small pieces, none of which was more than ¼ inch in diameter, thoroughly mixed and samples for the several analyses taken from this composite sample. Dry weight was determined by drying two 100 gram samples in forced draft at 70 degrees C. Separate 25 gram samples were used for carotene, ascorbic acid and carbohydrate determinations. Three hours or less elapsed from the time the beans were picked until the sampling of the fresh material was completed. Ascorbic acid was determined by a modification of the Morell (7) method. The method of Wall and Kelley (16) was used for carotene determinations. The sample for carbohydrate analysis was preserved by heating in 80 per cent alcohol for 45 minutes. The preserved material was ground to a very fine suspension in a Waring blendor and made to definite volume with 80 per cent ethyl alcohol. An aliquot of the suspension was filtered by centrifuging. Total and reducing sugars were determined on the alcohol fraction. The residue was hydrolyzed with 10 per cent HCl at 15 pounds pressure for 1 hour and the reducing power of the neutralized solution determined. The dry weight of the acid insoluble residue was determined. The reducing power of the various solutions was determined by the Shafer-Somogyi method as modified by Heinze and Murneek (3). The material dried for moisture determination was ground to pass a 40-mesh screen and used for nitrogen and mineral analysis. The micro-Kjeldahl method was used for organic nitrogen. A sample of the dried material was ashed at 450 degrees C with a stream of oxygen passing over, the ash dissolved in 10 per cent HCl and the amount of calcium, magnesium, potassium, sodium, sulfate, and phosphate in the solution determined by approved methods. Iron was determined by the Ortho-phenanthroline method of Saywell and Cunningham, as modified by Sheets and Ward (11). Manganese was determined by the method of Sommers and Shive (14).

Results

The effect of irrigation on the average composition of the beans is given in Table I. Increasing soil moisture by irrigation increased the size of the pods very markedly. The beans from the non-irrigated plots were wrinkled and had a generally poor quality. The greatest effect of irrigation was that of hydration. The beans grown on the non-irrigated plots averaged 10.8 per cent dry weight and the beans from the heavily irrigated plots averaged 8.6 per cent dry weight. When the results are expressed on a fresh weight basis, this difference in moisture is reflected in the concentration of the several constituents which were determined. For all constituents except potassium the average values were highest in the beans grown without irrigation, intermediate in

TABLE I—EFFECT OF IRRIGATION ON THE COMPOSITION OF SNAP BEANS

Constituent	No Irrigation	Light Irrigation	Heavy Irrigation	Heavy Irrigation in Split Application	Difference Necessary for Significance at Odds of	
					19 to 1	99 to 1
Fresh Weight						
Weight, per pod (gms)	4.40*	6.53	7.42	7.46	0.41	0.62
Dry weight (per cent)	10.8	9.4	8.6	08.8	0.98	1.48
Ascorbic acid (mgs per 100 gms)	22.4	18.3	17.1	16.1	2.18	3.30
Carotene† (mgs per 100 gms)	0.44	0.33	0.23	0.19	0.15	0.23
Reducing sugars (per cent)	2.40	1.99	2.13	2.17	0.16	0.24
Total sugar (per cent)	2.98	2.42	2.47	2.46	0.26	0.40
Acid hydrolyzable carbohydrate (per cent)	1.82	1.75	1.49	1.44	0.41	0.62
Acid insoluble residue (per cent)	0.83	0.79	0.84	0.81	0.16	0.27
Ash (per cent)	0.85	0.84	0.70	0.76	0.085	0.13
Calcium (per cent)	0.055	0.048	0.044	0.046	0.0080	0.0120
Magnesium (per cent)	0.026	0.022	0.018	0.020	0.0056	0.0085
Potassium (per cent)	0.31	0.32	0.26	0.28	0.025	0.039
Sodium (per cent)	0.013	0.011	0.010	0.010	0.0023	0.0035
Phosphate (per cent)	0.18	0.15	0.12	0.13	0.019	0.029
Nitrogen (per cent)	0.39	0.33	0.24	0.25	0.057	0.087
Sulphate (per cent)	0.09	0.08	0.07	0.07	0.012	0.018
Iron (mgs per 100 gms)	1.28	0.92	0.93	0.96	0.31	0.47
Manganese (mgs per 100 gms)	0.35	0.25	0.25	0.25	0.11	0.16
Dry Weight						
Ascorbic acid (mgs per 100 gms)	210.0	196.0	200.0	181.0	31.0	47.1
Carotene† (mgs per 100 gms)	4.0	3.3	2.6	2.3	1.7	2.6
Reducing sugar (per cent)	22.4	21.4	24.9	25.4	2.7	4.0
Total sugar (per cent)	27.9	25.9	28.8	27.9	1.7	2.6
Acid hydrolyzable carbohydrate (per cent)	16.9	18.2	17.5	16.3	2.7	4.0
Acid insoluble residue (per cent)	7.7	8.3	9.8	9.2	1.6	2.4
Ash (per cent)	7.9	8.8	8.2	8.5	0.60	0.90
Calcium (per cent)	0.52	0.51	0.51	0.52	0.11	0.28
Magnesium (per cent)	0.24	0.25	0.20	0.23	0.052	0.079
Potassium (per cent)	2.91	3.39	3.11	3.13	0.29	0.43
Sodium (per cent)	0.12	0.12	0.12	0.12	0.015	0.023
Phosphate (per cent)	1.64	1.59	1.44	1.43	0.17	0.26
Nitrogen (per cent)	3.6	3.5	3.1	3.1	0.31	0.47
Sulphate (per cent)	0.83	0.87	0.78	0.80	0.067	0.102
Iron (mgs per 100 gms)	9.9	10.3	10.8	10.9	1.02	1.55
Manganese (mgs per 100 gms)	3.2	2.7	3.0	2.8	0.91	1.37

*Each value is an average of eight determinations (four replications of two varieties each).
†Values for Black Valentine only.

those grown with light irrigation, and lowest in those grown with heavy irrigation. There was no significant difference in composition between the beans from the heavy irrigation plots and the split application plots. The difference between the beans from the light irrigation and those from the other treatments was not always significant, but in most cases the values were intermediate between the non-irrigated and heavily irrigated plots. The concentration of potassium on a fresh weight basis is less (but not significantly) in the beans from the non-irrigated plots than in those from the light irrigation plots. The two heavily irrigated treatments produced beans significantly lower in potassium than either the light or non-irrigation treatments. When the results are expressed on a dry weight basis most of the differences disappear; however, there are significant differences in the carbohydrate, organic nitrogen and potassium content on a dry weight basis. There is a significant difference in the total sugar expressed as per cent of the dry weight, the beans from the light irrigation plots having the lowest sugar content. These values are the average for both

varieties from each of the four replicates. The relatively low amount of total sugars in beans from the light irrigated plots is due largely to the low concentration of sugar in Black Valentine beans. There was little or no difference in total sugars in the Logan beans grown on different irrigation treatments. The per cent organic nitrogen decreased with increasing soil moisture both on a fresh and dry weight basis.

The ascorbic acid and carotene contents expressed as milligrams per 100 grams of dry weight show the same trend as on the fresh weight basis. The differences between treatments are much smaller and the variations within replicates are so great that there is no significance between treatments. It is of some interest, however, that the highest concentration of both constituents was found in the beans grown on the dry plots. When expressed on a dry weight basis, the ash constituents showed very little variation, the one exception being potassium, which was highest in the beans receiving light irrigation and lowest in those receiving no irrigation.

The differences between the two varieties (Table II) are small, the 0.9 per cent variation in dry weight and the difference in total sugar as already mentioned being the most important ones. The difference in moisture is reflected in the concentration of the various constituents. When expressed on a fresh weight basis there are differences between the varieties due to dilution but on a dry weight basis there is very little difference between them.

This difference between the beans from the various treatments seems rather small when the large difference in growth is considered. It is characteristic of fruits of a number of crops that they are rather uniform in composition, regardless of the conditions under which they are grown. Beans, apparently, are no exception to this rule.

What basis should be used in reporting the data, is one of the difficult problems in presenting results and discussing the chemical composition of vegetables. This problem is well illustrated by the data presented here. In many instances, values are reported only on one basis, either fresh or dry weight, and information is not included as to the per cent moisture, so it is impossible to change data to the other basis. This is especially true with respect to vitamin analyses. As is shown in this paper, it is possible to have large differences in ascorbic acid or carotene content when expressed as milligrams per 100 grams of fresh material but, when the amount of water in the tissue is considered, it is only a matter of dilution and not an actual difference in total amount. It is realized that most vegetables are consumed on a fresh weight basis and should be considered on that basis. However, from the plant physiological viewpoint or from the standpoint of actually measuring changes in the composition as a result of certain cultural practices, it would seem desirable to evaluate the analyses on both a fresh and dry weight basis.

Summary

Logan and Black Valentine snap beans were grown at four levels of soil moisture obtained by varying the amount of irrigation applied. The

TABLE II—AVERAGE COMPOSITION OF LOGAN AND BLACK VALENTINE SNAP BEANS GROWN AT FOUR LEVELS OF SOIL MOISTURE

	Weight Per Pod (Gms)	Dry Weight (Per Cent)	Ascorbic Acid (Mgs Per 100 Gms)	Carotene (Mgs Per 100 Gms)*	Reducing Sugars (Per Cent)	Total Sugars (Per Cent)	Acid Hydrolyzable Carbohydrate (Per Cent)	Acid Insoluble Residue (Per Cent)	Ash (Per Cent)	Calcium (Per Cent)	Magnesium (Per Cent)	Potassium (Per Cent)	Sodium (Per Cent)	Phosphate (Per Cent)	Nitrogen (Per Cent)	Sulphate (Per Cent)	Iron (Mg Per 100 Gms)	Manganese (Mgs Per 100 Gms)
Fresh Weight																		
Logan	6.68†	8.9	17.8	0.30	2.38	2.65	1.50	0.79	0.74	0.047	0.021	0.28	0.010	0.13	0.30	0.077	0.98	0.29
Black Valentine	6.22	9.8	19.1	0.30	1.96	2.51	1.75	0.85	0.82	0.049	0.022	0.30	0.012	0.15	0.33	0.078	1.06	0.26
Difference necessary for significance at odds of																		
19–1	0.38	0.33	2.2	—	0.19	0.10	0.18	0.034	0.029	0.0036	0.0041	0.016	0.00094	0.013	0.018	0.0024	0.18	0.033
99–1	0.53	0.47	3.3	—	0.28	0.14	0.25	0.047	0.042	0.0051	0.0057	0.022	0.0013	0.018	0.026	0.0034	0.26	0.046
Dry Weight																		
Logan	—	—	198.0	3.3	26.8	29.7	16.7	8.9	8.32	0.52	0.23	3.16	0.12	1.47	3.3	0.85	10.8	3.2
Black Valentine	—	—	195.0	3.0	20.3	25.5	17.7	8.7	8.37	0.50	0.23	3.09	0.12	1.57	3.4	0.79	10.1	2.7
Difference necessary for significance at odds of																		
19–1	—	—	13.3	—	2.4	1.7	2.0	0.60	0.26	0.027	0.012	0.16	0.0022	0.14	0.13	0.084	0.36	0.32
99–1	—	—	18.6	—	3.3	2.3	2.8	0.84	0.37	0.038	0.016	0.22	0.0031	0.19	0.19	0.118	0.51	0.45

*Statistical analyses not made because of four missing values for Logan varieties.
†Each value is an average of 16 determinations.

beans were analyzed for dry weight, ascorbic acid, carotene, reducing and total sugars, acid hydrolyzable carbohydrates, acid insoluble residue, organic nitrogen, total ash, calcium, magnesium, potassium, sodium, manganese, iron, sulfate, and phosphate. The greatest difference was one of hydration. The beans receiving no irrigation had higher per cent dry weight than those receiving irrigation. On a fresh weight basis, there was considerable variation in most of the constituents, however, on a dry weight basis, these differences either disappeared or became much smaller. It is pointed out that, in reporting chemical analyses of vegetables, care should be taken to give enough information on the per cent dry weight so that the difference due to the variations in the moisture content of the crops can be evaluated.

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Two Years Results of the Effect of Several Irrigation Treatments on the Yield of Cabbage and Snap Beans[1]

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THE annual precipitation for the State of Florida averages close to 52 inches, which would be adequate for the production of most vegetable crops, if it were spread uniformly over the entire year. However, the greater part of the rainfall occurs generally in the period from June to September. Thus, during the seasons when the majority of the Florida vegetables are grown, rainfall is generally light and irregular. Because of this irregularity, the major part of the commercial vegetable acreage is produced on soils where the moisture is often increased by various methods of irrigation. Irrigation tests with several vegetables in recent years in Florida by Volk and Winsor (4, 5) and Jamison (1) have demonstrated the need for further irrigation studies.

METHODS AND MATERIALS

To determine the effectiveness of irrigation in improving the yield and quality of vegetables over a period of years, a series of test plots were established at Gainesville in 1945. These plots were located on Arredondo loamy sand, the average moisture equivalent of which ranged from 6.04 to 9.24. A permanent overhead irrigation system was established consisting of an oscillating nozzle on a single upright for each individual plot. Individual plots were approximately $^1/_{24}$-acre in size and with sufficient aisle space between plots to prevent the overlapping of irrigation treatments.

For the past two years cabbage and beans have been grown as winter and spring crops respectively on the plots devoted to irrigation studies. During this period both vegetables were grown under four levels of moisture with the levels arranged in a Latin square. Moisture treatments given the vegetables were: (a) no irrigation; (b) light irrigation to maintain the moisture above the point where permanent wilting would occur; (c) heavy irrigation or twice the amount applied in (b) to maintain the soil moisture nearer the moisture holding capacity; and (d) the same amount of water as in the heavy treatment but applied in a split application. The applications of water used in the split application were made about 3 days apart.

During the first year, irrigation applications were timed by observing the visual characteristics exhibited by the vegetables indicating the need for water and by soil moisture determinations. The moisture determinations were made with a 50-gram sample of soil by the method described by Stout and Holben (2). With cabbage the amount of water applied at each individual irrigation varied from an application of ⅛ to ½ inch of water for the light irrigation treatment. With beans

[1]The writer wishes to express his appreciation to Dr. F. S. Jamison for assistance in planning the investigation and the establishment of the permanent irrigation system, and to Dr. G. M. Volk for the determination of the soil moisture equivalents.

the amount at each application was increased and varied from ¼ to ½ inch of water for the light irrigation treatment.

An evaporimeter was employed during the second year to assist in determining the time for application of irrigation water and an attempt was made to irrigate the vegetables after 1 inch of evaporation had been recorded from an open tank. The tank used was 48 inches in diameter and 10 inches deep. Soil moisture determinations were also made prior to each irrigation. The four moisture treatments were made by applying the following approximate amounts of water respectively for each treatment at the time of irrigation: (a) no water; (b) ½ inch of water; (c) 1 inch of water; and (d) 1 inch of water applied in two applications of ½ inch each. Applications in the latter treatment were made approximately 3 days apart.

During the two winter seasons the experimental area was planted to cabbage; the individual plots were divided into three equal sections to permit the study of a sub-treatment dealing with the application of nitrogenous fertilizer. These fertilizer sub-treatments were: (A) 1,600 pounds of an 8–7–5 fertilizer per acre; (B) 1,600 pounds of a 4–7–5 fertilizer plus additional nitrogen in the form of two side dressings each of 200 pounds per acre of nitrate of soda; (C) 1,600 pounds of a 4–7–5 fertilizer per acre. All fertilizers, except the side dressings, were applied at planting. The variety Copenhagen Market was planted in 1946 and the variety Glory of Enkhuizen was planted in 1947.

Two varieties of beans were planted each year, Florida Belle and Logan in 1946 and Stringless Black Valentine and Logan in 1947. In 1946, each of the two varieties used was planted at two spacings. One spacing was at the regular rate recommended with the bean planter employed which was approximately eight seed per foot of seed row. The second spacing tested was at a lighter rate of approximately six seed per foot of seed row, causing a wider spacing between plants. All bean plots received the same fertilizer treatment for both years which consisted of 1,200 pounds of a 4–7–5 fertilizer per acre. An additional side dressing of nitrogen and potassium was given the beans in 1947. Residual effect from previous cabbage fertilization was considered to be negligible.

Results

Precipitation during the 1945–1946 crop season was near normal while the precipitation for the 1946–1947 crop season was lower than normal. Normal precipitation (3) is compared in Table I with the measured precipitation during the periods which the several tested crops were grown. As a result of the distribution and amount of rainfall, the number of irrigations varied with the individual crop and season. The amount of irrigation water applied to each crop is given in Table II.

Cabbage:—The data in Table III show the effect of irrigation and fertilizer treatments on the yield of cabbage. During 1946, in which the precipitation was close to normal, no significant differences in the yield of cabbage were secured as a result of irrigation treatment. Small increases in the average yield occurred from the plots receiving the

TABLE I—COMPARATIVE PRECIPITATION RECORDS FOR THE PERIOD OF THE IRRIGATION STUDIES

Month	Rainfall (Inches)	
	Measured Precipitation	Normal Precipitation*
Cabbage—1945–1946		
November	2.00*	1.82
December	9.22*	3.21
January	2.21	3.16
February	2.53	2.92
Beans—1946		
March	2.55	3.35
April	1.88	2.40
May	7.22	3.15
Cabbage—1946–1947		
November	0.01**	1.82
December	0.23	3.21
January	1.55	3.16
February	4.34†	2.92
Beans—1947		
March	4.76‡	3.35
April	1.93	2.40
May	0.09§	3.15

*Weather Bureau Records, Gainesville Station.
**Measured only from November 21 to November 30.
†Measured only from February 1 to February 15.
‡Measured only from March 12 to March 31.
§Measured only from May 1 to May 12.

TABLE II—NUMBER OF INCHES OF IRRIGATION WATER APPLIED TO CABBAGE AND SNAPBEANS

Year	Crop	Irrigation Treatment		
		Light	Heavy	Split Application
1945–1946	Cabbage	1.12*	2.44*	2.11*
1946	Beans	1.40	2.84	1.80
1946–1947	Cabbage	3.04	5.41	4.89
1947	Beans	3.50	7.04	6.52

*Initial irrigation at planting not included.

light and split application of irrigation. The results of the 1947 growing season, which had less rainfall, were more pronounced and highly significant differences in yield were secured as a result of treatment. This increase was secured despite the fact that freezing weather near the end of the season prevented the normal heading of cabbage and necessitated the harvesting of the cabbage at an immature stage. The highest average yield of cabbage for that season was harvested from the plots irrigated by the split application method of applying a total of 1 inch of irrigation water in two applications, each application consisting of ½ inch of water. The stand of cabbage was also affected as a result of irrigation treatment and a larger number of cabbage replants were required on plots receiving no irrigation.

Results from the fertilization study reveal that significant differences occurred between treatments in 1946 with the highest average yield of 7.97 tons of cabbage per acre being harvested from plots fer-

TABLE III—THE EFFECT OF SEVERAL IRRIGATION AND FERTILIZER TREATMENTS ON THE AVERAGE YIELD OF CABBAGE

Fertilizer Sub-Treatments	Tons Per Acre				
	Irrigation Treatment				Average for Fertilizer Treatments
	None	Light	Heavy	Split	1945-1946*, 1946-1947
	1945 1946 Season				
8-7-5	5.03	5.87	5.13	5.19	5.31
4-7-5 plus side-dressing	7.30	9.27	8.00	7.30	7.97
4-7-5	5.24	5.38	4.28	5.49	5.10
Average for irrigation treatments	5.86	6.84	5.80	5.99	—
	1946–1947 Season				
8-7-5	2.28	5.07	5.40	6.76	4.88
4-7-5 plus side-dressing	2.28	5.31	6.06	6.46	5.03
4-7-5	2.49	5.34	5.86	7.08	5.19
Average for irrigation treatment**	2.35	5.24	5.77	6.77	—

*F value highly significant.
**L.S.D.: 1 per cent 2.03; 5 per cent-1.34.

tilized with 1,600 pounds of a 4–7–5 fertlizer plus additional nitrogen in the form of two side dressings. However, in 1947 no significant differences in yield resulted from different fertilizer treatments.

Beans:—The effect of the several irrigation treatments on the average bushel yield of beans is given in Table IV. Irrigation was a factor contributing to the increase of bean yields for both seasons. In 1946, the average yield of beans was found to be significantly affected by irrigation treatment. The highest average yield of 176.2 bushels per acre was harvested from plots irrigated with the split application method of irrigation followed closely by an average yield of 174.3 bushels per acre harvested from the plots receiving the light irrigation treatment. During the second year in a drier season, irrigation treatments were found to be highly significant. The highest average yield of 291.2 bushels per acre was harvested from the plots receiving the split appli-

TABLE IV—THE EFFECT OF SEVERAL IRRIGATION TREATMENTS ON THE AVERAGE YIELD OF SEVERAL VARIETIES OF SNAPBEANS

Varieties	Yield of Beans (Bushels Per Acre)				
	Irrigation Treatment				Average for Varieties 1946 and 1947**
	None	Light	Heavy	Split	
	1946 Season				
Florida Belle	153.3	168.5	153.6	174.0	162.4
Logan	138.9	180.2	154.3	178.4	162.9
Average for irrigation treatment*	146.1	174.3	153.9	176.2	—
	1947 Season				
Stringless Black Valentine	22.5	180.6	231.0	274.1	177.1
Logan	25.4	213.6	229.7	308.3	194.3
Average of irrigation treatment†	24.0	197.1	230.4	291.2	—

*1946 L.S.D.: 1 per cent–14.7; 5 per cent–22.3.
**1947 L.S.D.: 1 per cent–25.0; 5 per cent–16.5.
†1947 L.S.D.: 1 per cent–18.4; 5 per cent–12.1.

cation treatment of irrigators, whereas those plots receiving no irrigation produced an average yield of 24.0 bushels of beans per acre.

From the data in Table IV it can be observed that all varieties of beans studied generally exhibited similar reactions to irrigation treatment. No differences between the yield of varieties Logan and Florida Belle were secured in 1946. Logan, however, yielded significantly more beans than the variety Stringless Black Valentine in 1947. In that year the average yield of Logan was 194.3 bushels per acre compared with 177.1 bushels per acre of Stringless Black Valintine. No significant interactions were found either year.

The planting of the bean seed at the rate of eight seed per foot of seed row produced a significantly larger yield of beans than those bean seed planted at a rate of six seed per foot during the 1946 season. The spacing experiment was not conducted in 1947.

Summary

With both cabbage and beans irrigation is of importance in assuring continued high yields when grown in seasons of near normal precipitation as well as in drier seasons. An even supply of moisture in the soil is essential for best average results with cabbage and beans as evidenced by the yields secured from these vegetables for the two seasons when irrigated with the split application method of irrigation. In periods of normal rainfall, light irrigation appeared to be effective in maintaining the yield of cabbage and beans.

Side dressings of cabbage with additional nitrogen in the form of nitrate of soda appear to be more effective in increasing yields during seasons with near normal precipitation.

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Breeding Rust Resistant Pole Green Beans for Hawaii[1]

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IN 1937, Parris (6) reported serious damage of pole green beans in Hawaii caused by rust *(Uromyces appendiculatus) (Uromyces phaseoli typica)*. In 1941, Matsuura and Parris (5) reported that three strains of rust were likely present. In 1942 Tachibana and Frazier (7) announced initiation of a hybridization program to develop a rust resistant, heavy yielding, flat podded pole bean to replace the Lualualei variety which had been grown widely for many years, but which was susceptible to rust. The breeding program was begun only after rust resistant pole green bean varieties had been acquired from various sources and all of them found undesirable, either because of low yielding ability, or unacceptable market appearance. Brief progress reports have been published by Hendrix, Tachibana, and Matsuura (4) and by Frazier and Hendrix (1).

CROSSES

Approximately 175 crosses, involving pole x pole, pole x bush, and bush x pole varieties were made from 1942 to 1945. Crosses in 1944 and 1945 were made largely between outstanding selections in progeny of hybrid lines. In most hybrids Lualualei has been involved as a rust susceptible parent that would contribute earliness, heavy yielding ability, and flat, smooth pods. For rust resistance such varieties as Hawkesbury Wonder, Asgrow Stringless Green Pod, Kabuto (Oriental rust resistant pole variety), Black Valentine, Bountiful, Plentiful, Rust Resistant Kentucky Wonder, U. S. No. 5 Refugee, Tenderpod, Streamliner, Pencil Pod Black Wax, Burpees Stringless Green Pod, Long Island Long Pod, and Tendergreen, have been used as one parent.

TESTING METHOD

From 1944 through 1947, all bean plantings were made at the Makawao, Maui, sub-station of the Hawaii Agricultural Experiment Station, where, at an elevation of 2300 feet, the temperature and humidity are ideal for development of rust epidemics (3). At this location, day temperatures range from 70 to 80 degrees F, and night temperatures range from 50 to 60 degrees F. Heavy dews and frequent light showers result in wetting of bean foliage for extended periods of time. Six crops have been planted at this location, and in each case severe epidemics of rust have developed. Although artificial inoculation has been unnecessary in the development of epidemics, spores collected on the islands of Maui and Oahu have been introduced on the plants as a precaution in maintaining, presumably, a collection of the races present on these islands.

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Rust readings on individual plants or lines have been based on the following key:

5. Severe — sori very abundant; plant severely injured.
4. Moderate — fewer sori but considerable injury.
3. Slight — few sori; very little injury.
2. Trace — sori rare.
1. Flecking — necrotic spots on leaves, but no sori.
0. None — neither sori nor necrotic flecks.

All individual plant selections, made for resistance to rust and desirable vine and pod characters, have had readings of 0 to 3. No lines have been carried which had plants with average readings above 3.

Status of Resistant Lines

The most advanced lines are now in the tenth generation. Lines from Hawaii Experiment Station selection 494, progeny of a cross of Bountiful x Lualualei and lines from selection number 573, progeny of a cross of (Pencil Pod Black Wax x Lualualei) x (Bountiful x Lualualei) have been especially promising for rust resistance, yield, and vine and pod characters. Of the two, line 494 appears to be of greatest promise. Yields of this line are excellent. Rust readings have not been above class 2, vines have good vigor, and pod appearance and edible quality compare favorably with Lualualei. Pods are relatively straight and flat, with lengths of 7 to 9 inches, and widths of about ½ inch, compared to the flat, straight pods of Lualualei with lengths of 7 to 8 inches and widths of about ½ inch. Pod smoothness is not as good as Lualualei, but is satisfactory for general market appearance. In order to check the rust resistance of promising lines on all of the major Hawaiian islands (Hawaii, Maui, Oahu, Kauai and Molokai), tests with farmers in cooperation with the Hawaii Agricultural Extension Service, were made in 1946, and are again under way in the fall of 1947. The 1946 tests indicated that thus far the resistance to rust has been satisfactory throughout the islands. It is fully recognized, however, that there is an ever present possibility of appearance of a new rust strain that may destroy the effectiveness of these lines (2). Since the lines are, at the present time, satisfactory rust-resistant substitutes for Lualualei, no further hybridization work is contemplated. If resistance to rust is maintained, it may be expected that a named variety will be released in 1948 or 1949. At that time, a more detailed account of the development and of the characteristics of the material will be published by the Hawaii Agricultural Experiment Station.

It has not been feasible to continue studies of strains of rust present in the islands, or to study in detail the inheritance of resistance to rust. Value of the lines to breeders elsewhere, therefore, is a matter of conjecture. However, small seed lots are available for breeders who may wish to test them.

Summary

A brief account of the development of rust resistant pole green beans for Hawaii is given. Relatively vigorous, heavy yielding types

with long, flat pods of fair edible quality are available to replace the present rust susceptible Lualualei variety. No further hybridization for rust resistance is contemplated, unless a new strain or strains of rust necessitates such work.

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Natural Crossing in Lima Beans in Southern California in 1946

By Roy Magruder, *Plant Industry Station, Beltsville, Md.*

During 1942 to 1946 the writer had the opportunity of observing lima bean seed growing in California and was surprised at the purity of seed stocks in view of the lack of isolation of different varieties. It was common practice to plant bush and pole varieties in adjacent rows and in many instances white and colored-seeded varieties were contiguous. In view of the results obtained over the years from such practices, one is forced to conclude that the amount of field crossing in limas in California is much smaller than that reported for Maryland (3, 4) and for Alabama (1).

It is the purpose of this paper to report some data on the amount of field crossing in four varieties of bush lima beans grown in southern California in 1946.

Materials and Methods

During the summer of 1946, two plots of lima beans were grown at the United States Horticultural Field Station, LaJolla, California, located at Torrey Pines.

One plot consisted of an increase block of a new variety of bush lima known as U. S. 343 in which were found 11 viner plants—probably the result of hybridization in an earlier generation. Seed was saved separately from the plants of U. S. 343 on each side of each viner. The distance between the viner and each selected plant of U. S. 343 is given in Table I. The rows were 3 feet apart.

A second plot contained a large number of breeding lines of dif-

TABLE I—Percentage of Viner Hybrids in U. S. 343 Bush Lima Bean, the Seed Parent Having Grown at Various Indicated Distances From a Viner Grown at Torrey Pines, California (1946)

Plant Number	No. of Plants	No. of Viners	Per Cent Viners	Distance of Seed Parent From a Viner (Feet)
1 E*	18	1	5.5	3.0
1 W	21	0	0	1.0
2 E	26	0	0	0.5
2 W	28	0	0	0.5
3 E	40	0	0	1.5
3 W	17	0	0	2.0
4 E	13	0	0	1.0
4 W	29	0	0	1.5
5 E	31	0	0	5.0
5 W	41	0	0	5.5
6 E	30	0	0	1.5
6 W	12	0	0	1.0
7 E	22	0	0	3.5
7 W	13	2	15.4	1.5
8 E	21	0	0	1.0
8 W	35	0	0	4.5
9 E	17	0	0	6.0
9 W	10	0	0	0.5
10 E	26	0	0	2.5
10 W	29	0	0	1.5
11 E	27	0	0	1.5
11 W	32	2	6.25	0.5
Total	538	5	0.93	—

*E = east of viner; W = west of viner. Distance given in column 5.

ferent plant and pod types interspersed with rows of commercial varieties as checks. The rows were spaced 3 feet part. One row each of the Henderson, Peerless, and Early Market varieties, surrounded by rows of different type, was selected for the study of field crossing. The Henderson row was surrounded on all sides by large plants with gray-green leaves, the Peerless (6) row by smaller plants bearing smaller pods and smaller, darker green leaves, and the Early Market (5) row by smaller plants with smaller pods and leaves.

Seed was saved from individual plants and the number of selected plants of the three varieties is given in Table II. Planting was done in the spring of 1947 at the Plant Industry Station, Beltsville, Maryland, in rows 3 feet apart. Seed was dropped 6 inches apart. Due to a heavy rain which crusted the soil following planting, the germination and number of plants available for study was lowered on the Peerless and Early Market varieties. There was ample space for normal development of all three varieties.

Viner-type hybrids were counted and removed on August 4. The detailed study of each plant for pod type was not made until September 2 at which time the pods were fully developed on all varieties and

TABLE II—Percentage of Recognizable Hybrids in Families of Henderson, Peerless, and Early Market Bush Limas Grown at Torrey Pines, California (1946)

Variety and Plant Number	No. Plants	No. Hybrids	Per Cent Hybrids
H 1	120	0	0
2	96	0	0
3	100	0	0
4	130	0	0
5	160	0	0
6	79	0	0
7	90	0	0
8	125	0	0
9	52	0	0
10	226	0	0
Variety total	1,178	0	0
P 1	103	0	0
2	58	1	1.7
3	86	0	0
4	40	0	0
5	19	0	0
6	26	0	0
7	94	1	1.1
8	54	0	0
9	77	0	0
10	75	1	1.3
11	106	1	0.9
12	70	0	0
Variety total	808	4	0.49
EM 1	78	0	0
2	26	0	0
3	37	2	5.4
4	15	0	0
5	62	0	0
6	40	0	0
7	18	0	0
8	16	0	0
9	11	0	0
10	7	0	0
11	30	0	0
12	27	0	0
13	24	0	0
14	31	1	3.2
Variety total	422	3	0.71

partially dry on Henderson. The hybrids were easily distinguished, usually by several characteristics.

Results

A total of only five vine-type hybrid plants were found among three of the 22 families of U. S. 343 (Table I). The percentage of hybrids for the variety as a whole was less than 1 per cent (.93 per cent). There seemed to be no relation between the distance of the bush type plant from the viner type and the percentage of hybrids.

No hybrids were found in the 1,178 progeny of the 10 Henderson plants (Table II).

In the 808 progeny of the 12 plants of the Peerless variety, a single hybrid plant was found in each of four families. In all cases the pods on the hybrid plant were earlier maturing than Peerless; in three cases they were flatter and in the other one thicker than Peerless. The percentage of hybrids for the variety as a whole was approximately .49 per cent.

In the Early Market variety, only two out of 14 families contained one and two hybrids, respectively, among the entire 422 plants grown. In all cases, the hybrid plants bore pods that were shorter, flatter, and earlier than Early Market and were also easily recognized by the different plant characteristics. For the variety as a whole, the percentage of hybrids was approximately .71 per cent.

In the total of 2946 plants grown from the four varieties there were only 12 recognizable hybrids, or .4 per cent.

Discussion

These data clearly indicate that even where maximum opportunity is given for crossing (as in the case of the U. S. 343 plants), the percentage of natural crosses in the field at Torrey Pines, California, in 1946 was much lower than that reported for Maryland (3, 4) or for Alabama (1) where maximum opportunity for crossing was not afforded. The data (Table II) from material grown in adjacent rows also show a lower percentage of hybrids under the conditions of this experiment than was reported for comparable conditions of planting in Maryland or in Alabama, but agree with those of Mackie (2) for California.

The reason why there is less natural crossing in California than in the East and South may be partly the smaller population of bees and other insects capable of effecting cross pollination and partly the conditions that restrict the flight of bees and other insects. Observations at Torrey Pines and other coastal regions of southern California where lima bean seed growing is an important activity, indicate that there are fewer bees, and especially bumble bees, in California fields than in Maryland fields of limas at blooming time. The fogs which blanket most of the coastal lima-growing sections of California for a portion of each morning restrict the working period of bees and other insects and may be responsible in part for the low natural crossing rate in California.

Summary

The percentage of recognizable hybrids in four varieties of bush lima beans grown at Torrey Pines, California, in 1946 was much smaller than for the same or similar varieties grown in other years in Maryland and in Alabama.

U. S. 343, grown on each side of a viner-type plant, showed only .93 per cent of hybrids in the progeny of 22 plants.

When the rows of plants of Henderson, Peerless, and Early Market were surrounded by plants with contrasting characters, the percentages of recognizable hybrids found in their progeny were 0.0 per cent, .49 per cent, and .71 per cent, respectively.

The low percentages of field crossing at Torrey Pines may have been due to the smaller population of pollinating insects and their reduced activity caused by morning fogs.

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The Effect of Alpha-Naphthaleneacetic Acid on Certain Varieties of Lima Beans[1]

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In the irrigated areas of semi-arid Washington lima bean plants have been observed to set over a longer period of time when planted during late May and early June than during the latter part of June. This situation is due to the fact that weather conditions are usually more favorable for the first pods to set in the earlier than in the later plantings. Thus, early plantings may yield beans with a great range in maturity, often being set in two distinct periods, resulting in what is called a split-set. Late-planted beans start blossoming when weather conditions are usually least favorable for pod set, that is, the temperatures are high and the humidity low. As a result, the plant usually attains a state of full bloom before weather conditions become favorable for pod setting.

Thus, there are two objectives in this pod setting study, (a) to delay blossom set until the plant is in full bloom so as to obtain maximum green bean yields of uniform maturity; and (b) to set pods after the lima bean plant has come into full bloom when weather conditions are unfavorable for this plant function.

Since the snap bean has been more responsive than other bean crops to the application of different growth substances most of the research work has been with this crop (1, 3).

Fisher and Wittwer (1) report some work with lima beans and Wester (2) worked solely with this crop. All of these investigators have included alpha-naphthaleneacetic acid in their studies.

This paper presents the results of studies as to the effects of alpha-naphthaleneacetic acid spray on the growth, yield, maturity and seed development of three varieties of lima beans.

Materials and Methods

Three varieties of lima beans, Henderson Bush, Peerless and Fordhook 242 were seeded May 30 with commercial equipment in rows 30 inches apart at the Irrigation Experiment Station near Prosser, Washington. Each variety was replicated three times in a randomized arrangement. All five alpha-naphthaleneacetic acid treatments were randomized in each replicate of each variety. A treatment consisted of one row 33 feet long with at least one or more border rows separating it from the next treatment. All rows were thinned so that the stand of a given variety was approximately the same: Henderson — 75 plants; Peerless — 57 plants; and Fordhook 242 — 35 plants.

The only "growth substance" used in this study was alpha-naphthaleneacetic acid as supplied in the commercial product Parmone. The

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following treatments were all applied as sprays with a 3-gallon hand sprayer:

1. 0.5 per cent Carbowax 4000 in water.
2. 5 ppm alpha-naphthaleneacetic acid spray in 0.5 per cent Carbowax 4000.
3. 50 ppm alpha-naphthaleneacetic acid spray in 0.5 per cent Carbowax 4000.
4. 100 ppm alpha-naphthaleneacetic acid spray in 0.5 per cent Carbowax 4000.
5. 1000 ppm alpha-naphthaleneacetic acid spray in 0.5 per cent Carbowax 4000.

The rate of application varied from 75 to 100 gallons per acre. Details concerning the time of application of alpha-naphthaleneacetic acid and existing weather conditions are presented in Table I.

TABLE I—SPRAY SCHEDULE AND WEATHER CONDITIONS

Date Applied	Time	Treatments	Maximum Temperature (Degrees F)	Relative Humidity (Per Cent)	Weather
Jul 16	4 p m	All	94	36	Clear, very light breeze
Aug 1	10 a m	2, 3, 4	90	32	Clear, still
Aug 12	3 p m	2	90	28	Hazy, still

As pod set was fairly uniform all pods of a given variety were harvested at one time: Henderson — September 9; Peerless — September 14; and Fordhook 242 — September 22. Data included plant count, yield of pods and shelled beans, percentage whites by weight (determined after boiling 3 minutes) number of pods per pound and number of beans per pod.

The data, where complete in all replicates, were analyzed by analysis of variance.

DISCUSSION OF RESULTS

Wittwer and Murneek (3) in their hormone studies reported very undesirable and modifying effects on the foliage and pods of snap beans. Fisher (1) reported modification of the leaflets of the Henderson Bush when dusted with alpha-naphthaleneacetic acid of a concentration of 60 ppm or greater. Wester (2) using this same material noted only foliar color differences in lima beans receiving 0.5 per cent spray and 0.2 per cent dusts concentrations. The day following the first application of alpha-naphthaleneacetic acid on July 16, all three varieties of lima beans being studied, in all treatments except treatments 1 and 2, showed slight to severe epinasty in direct proportion to the concentration applied. Within a period of three to five days this condition became less apparent, while a deeper foliar color difference became noticeable. Leaves of the affected plants appeared to be wilted, yet the foliage was crisp but not brittle. By harvest time, however, these leaves became thick and leathery and broke easily on bending. Plants receiving 1000 ppm of alpha-naphthaleneacetic acid were most severely affected. They showed very little new growth or blossoming after

one spray application. At harvest many of the top petioles receiving this concentration were leafless. Some leaves showed a rusty appearance and suberization along the veins. In leaves showing the worst affects the suberized veins were cracked. The base of petioles and nodes of stems were enlarged and malformed. No virus appearance, vein-clearing or distortion of leaves was noted as has been reported (1) for snap beans. Root development of those varieties receiving 1000 ppm was short, thickly matted, very fibrous and unhealthy in color and general appearance.

The data presented in Table II confirm the observations made in the field. Yields of pods and shelled beans were significantly reduced by concentrations of 50 or more ppm when compared with the control

TABLE II—The Effect of Alpha-Naphthaleneacetic Acid on the Yield, Pod Size, Seed Set and Maturity of Three Varieties of Lima Beans

Treatment	Yield		Per Cent Whites by Weight	Average Number	
	Pods (Lbs)	Shelled Beans (Lbs)		Pods Per Pound	Beans Per Pod
Henderson Bush					
1. Water plus Carbowax	27.8	7.03	35.4	114	2.46
2. 5 ppm ANA* plus Carbowax	24.6	6.88	35.6	114	2.43
3. 50 ppm ANA plus Carbowax	21.9	5.18	24.6	108	2.33
4. 100 ppm ANA plus Carbowax	19.8	3.40	27.7	109	2.20
5. 1000 ppm ANA plus Carbowax	4.4	0.51	7.9	107	2.01
Peerless					
1. Water plus Carbowax	32.6	6.39	15.1	45	2.44
2. 5 ppm ANA* plus Carbowax	31.6	6.91	21.1	45	2.44
3. 50 ppm ANA plus Carbowax	17.0	3.44	15.4	47	2.22
4. 100 ppm ANA plus Carbowax	13.1	2.52	12.9	45	1.62
5. 1000 ppm ANA plus Carbowax	0.5	0.11	1.7	50	1.35
Fordhook 242					
1. Water plus Carbowax	25.5	5.82	14.4	128	3.02
2. 5 ppm ANA* plus Carbowax	26.9	6.39	13.1	124	2.97
3. 50 ppm ANA plus Carbowax	20.3	4.62	16.6	124	3.07
4. 100 ppm ANA plus Carbowax	9.5	1.55	13.8	123	2.89
5. 1000 ppm ANA plus Carbowax	0.4	0.14	20.0	85	2.83
L.S.D. at 5 per cent point between treatments	3.7	1.06	—	—	—
L.S.D. at 1 per cent point between treatments	5.0	1.45	—	—	—

*ANA—alpha-naphthaleneacetic acid.

treatments. Those pods that were set appeared to have set sometime later as indicated by maturity (percentage of whites) and that in at least two varieties bean set was reduced (average number beans per pod). Plants sprayed with water plus Carbowax and those sprayed with 5 ppm alpha-naphthaleneacetic acid showed no visible or meassureable differences. Fordhook 242 was observed to be slightly more affected by the different concentrations of the growth substance than the other varieties. This noticeable difference might have been due, however, to the poorer stand obtained of this variety.

Pod size appeared to be most seriously affected in the Henderson variety, but hardly at all in the other two varieties, except possibly for Fordhook 242 sprayed with 1000 ppm of alpha-naphthaleneacetic acid.

The results of this experiment did not give much encouragement in obtaining the objectives listed at the beginning of this paper.

Existing weather conditions at blossom time largely determine the pod setting of lima beans. In some cases, however, insects may also be a serious problem. Separate insecticide studies (4) were conducted in connection with the work reported herein. Check plots failed to show that insects were present in sufficient quantity to have been an influence on blossom set or pod development.

Undoubtedly the high temperatures and the low humidities that are normal for this region are responsible to a great extent for the damaging effects of alpha-naphthaleneacetic acid. The manner in which this material was applied could also be a contributing factor.

Summary

Alpha-naphthaleneacetic acid (Parmone) as used in these experiments significantly reduced plant growth and the yield of both pods and beans of Henderson Bush, Peerless, and Fordhook 242 limas, when applied as sprays in concentrations of 50, 100 and 1000 ppm.

There is an indication that the higher concentrations of alpha-naphthaleneacetic acid reduced pod size, seed set and retarded maturity, at least for certain varieties.

Except for the check and 5 ppm, all treatments caused from moderate to severe retardation in plant growth of all varieties. The foliage took on a darker green color, became thick and brittle, often cracked and in some cases abscissed. The only marked distortions noted occurred at nodes and basal portion of the petiole which became much enlarged and malformed.

The results suggest that the climatic conditions under which these studies were conducted and the spray type of application employed makes the use of this growth substance more hazardous in this region than has been found in certain other sections of the United States.

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The Influence of Various Row and Plant Spacings on Yields of Lima Beans[1]

By R. E. LARSON and LI PENG-FI, *Pennsylvania State College, State College, Penn.*

CONSIDERABLE interest and some differences of opinion have been shown by growers as well as research workers on the relation of plant spacing to yield and grade of the different vegetable crops for processing. Lima beans, the production of which has increased rapidly in Pennsylvania during recent years, have provided a particularly controversial subject in regards to this relationship. Lachman and Snyder (3) obtained positive correlations between yields and plant stands of Fordhook bush lima beans, with planting distances varying from 3.5 inches to 15 inches between plants in rows spaced 3 feet apart. A study made on Long Island by White-Stevens and Hartman (7) on the same variety led to similar conclusions. They stated that greatest yields were obtained with a planting of two beans every 9 inches or one bean every 4.5 inches. Results obtained with the variety Henderson's Bush are inconsistent and are indicative of the extreme influence of the environment on production. Matthews (6) in work conducted a short distance from College Park, Maryland found a positive relationship between plant stands and yields. Mahoney *et al* (5) in studies conducted at Ridgely, Maryland reported no relationship between rates of seeding and yield of Henderson's bush lima beans. They stated, however, that yields of Early Baby potato were significantly better at the regular rate of 4.8 plants per yard, than at the heavy or extra heavy seedings, and conversely the variety Maryland thick seeded showed a positive correlation between stand and yield.

This preliminary study has been conducted to determine the most efficient row and plant spacings for the production of Henderson and Fordhook type lima beans, under various soil and climatic conditions of Pennsylvania.

In these tests, 20-, 30-, and 40-inch row spacing treatments were used. Spacings between plants within the rows, were 2, 4, or 8 inches, excepting in Centre County where a poor stand resulted in actual spacings, of 4, 8, or 16 inches. A modified split plot design was used in which the plots with different row spacings were laid out parallel to, but at random in each of the three replicates. The variety plots of Thorogreen and Fordhook 242 were parallel to and randomized within each of the plots representing the respective row widths. Guard rows were grown between each of the row spacing and variety plots. The three plant spacing treatments were crosswise to and randomized within each of the row spacing plots. Double 20-foot rows were planted in each subplot. The various plot dimensions were, replicates 45 by 60 feet; row spacing plots, 10 by 60, 15 by 60, and 20 by 60 feet; variety

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plots 5 by 60, 7.5 by 60, and 10 by 60 feet; and plant spacing plots 5 by 20, 7.5 by 20, and 10 by 20 feet. The required number of seeds for each spacing was obtained by count. All seed was treated with Spergon. An application of 1000 pounds of 5–10–5 chemical fertilizer per acre was broadcast and plowed under at the Centre and Erie County locations; at York, the application was 500 pounds per acre. The first planting was made on the Chenango soils of Erie County on May 22, 1947. Exceedingly heavy rainfall and cool weather resulted in less than 10 per cent germination and necessitated replanting which was done on June 24th. The remaining two plantings were made on the Chester soils of York County and the Hagerstown soils of Centre County on May 27 and June 3 respectively. Final counts indicated approximately 90, 90, and 50 per cent stands for Erie, York and Centre counties respectively.

Simulating conditions followed in the processing industry, a single harvest was made at the time the plants appeared to be bearing the optimum number of edible beans. The weight of usable pods and beans was recorded, and a sample of 50 pods was taken at random from each subplot in order to determine the percentage of shelled beans. All yields were subsequently converted to pounds of shelled beans per acre. The data were interpreted statistically for each location by means of the analysis of variance.

Fordhook 242

In Tables I, II, and III are presented the mean yields of Fordhook 242 lima beans as influenced by the various row and plant spacings at each of the three locations. Significant F values were obtained for row

TABLE I—The Effect of Various Row and Plant Spacings on Yields of Fordhook 242 Lima Beans (Pounds Per Acre of Shelled Beans) Erie County, 1947

Width of Rows (Inches)	Spacing Within Rows (Inches)			Mean*
	2	4	8	
20	911	661	491	688
30	1,133	823	598	851
40	763	477	552	597
Mean†	936	654	547	—

*Significant difference—183.0 pounds.
†Significant difference—218.1 pounds; highly significant difference—306.2 pounds.

TABLE II—The Effect of Various Row and Plant Spacings on Yields of Fordhook 242 Lima Beans (Pounds Per Acre of Shelled Beans) York County, 1947

Width of Rows (Inches)	Spacing Within Rows (Inches)			Mean*
	2	4	8	
20	1,491	2,289	2,040	1,940
30	2,602	1,851	1,347	1,933
40	1,644	1,469	1,094	1,402
Mean†	1,912	1,870	1,494	—

*Significant difference—390.6 pounds.
†Significant difference—237.5 pounds; highly significant difference—333.7 pounds.
Interaction of row spacings by plant spacings—
Significant difference—412.3; highly significant difference—578.8.

TABLE III—THE EFFECT OF VARIOUS ROW AND PLANT SPACINGS ON YIELD OF FORDHOOK 242 LIMA BEANS (POUNDS PER ACRE OF SHELLED BEANS) CENTRE COUNTY, 1947

Width of Rows (Inches)	Spacing Within Rows (Inches)			Mean*
	4	8	16	
20	2,835	2,118	1,823	2,259
30	2,464	1,490	1,083	1,679
40	1,718	1,066	652	1,345
Mean†	2,339	1,758	1,186	——

*Significant difference—670.3 pounds.
†Significant difference—312.2 pounds; highly significant difference—438.3 pounds.

spacings and highly significant F values for plant spacings at each location, indicating distinct variations in mean yields of the various spacing treatments. The data from the York and Erie locations indicate that 30 inches between rows may be most practical. Although larger yields were obtained in Centre County because of ideal developmental weather, the data are not directly comparable with those from the other locations because of the poor stand obtained at the former location. The 20- and 30-inch row spacings at the Centre and York locations can be compared by using the 4- and 8-inch data in the tables. This would indicate a probable advantage in spacing the rows less than 30 inches apart providing the plant spacing within the row is adequate.

Because of the relatively late replanting of lima beans in Erie, blossoming began during the hot and dry weather of mid-August. The climatic conditions adversely affected fertilization and fruit set and resulted in a large percentage of blossom drop. Cordner found, as reported by Mahoney *et al* (5), that late June plantings consistently produced poorer yields than did plantings in May or July. He also presented evidence (2) indicating that the greatest numbers of pods developed when setting was permitted on basal nodes, that blossom abscission is associated with high air temperatures and a dry atmosphere, and that the critical time is in the early part of the blooming period of the raceme. Racemes failing to set at that time are characterized by low final set.

Inasmuch as the production per plant was small, the plants continued to blossom freely during the latter part of the season. Because of the aforementioned conditions the individual fruits on any one plant ranged from completely immature to dry beans at the time of harvest. Competition among plants at the closer spacings was indicated by the color of their foliage. Plants in the 20-inch rows were definitely yellow in color, particularly at the 2- and 4-inch plant spacings. In the 30- and 40-inch rows the foliage colors were pale green and green respectively. The intensity of the green color deepened within each of the various row treatments as the spacing within the rows was increased. It is evident that the competition among plants in the 20-inch rows plus the probable shading effects caused by their proximity resulted in a lesser production than was obtained in rows of 30 inches. The difference in means of the 20- and 30-inch row plots, Table I, was 163.0 pounds which is not statistically significant but closely approaches the

required difference at odds of 19:1. The coefficient of variability for row treatments in the Erie test was 19.6 per cent. A more extensive test would probably have shown a difference of such magnitude as to be significant.

An inverse relationship between plant spacings within the row and yields was established at all locations. The difference between the 2- and 4-inch spacing means at York is minor because of the greatly reduced yields obtained from the highly competitive 2- by 20-inch spacing. It is evident that in the 30- and 40-inch rows the increase from 2 to 4 inches in distance between plants resulted in decreased yields, (Tables II and VII).

The only significant interaction between row by plant spacings for Fordhook 242 lima beans was obtained at York and is due to the conditions previously stated. The primary differential responses include the variations caused by the 2- by 20-inch treatment in comparison with any of the other combinations. It is probable that competitional effects for nutrients and moisture at a spacing of 2 by 20 inches and the probable shading due to the proximity of the plants with its adverse relation to fruit set, may be responsible for these differential results. It will be noted in Table II that differential responses of lesser magnitude also were obtained.

TABLE IV—The Effect of Various Row and Plant Spacings on Yields of Thorogreen Lima Beans (Pounds Per Acre of Shelled Beans) Erie County, 1947

Width of Rows (Inches)	Spacing Within Rows (Inches)			Mean
	2	4	8	
20	617	584	423	541
30	539	554	374	489
40	435	352	381	389
Mean	530	496	392	—

TABLE V—The Effect of Various Row and Plant Spacings on Yields of Thorogreen Lima Beans (Pounds Per Acre of Shelled Beans) York County, 1947

Width of Rows (Inches)	Spacing Within Rows (Inches)			Mean
	2	4	8	
20	949	922	720	864
30	1,270	973	649	964
40	866	628	587	694
Mean*	1,028	841	652	—

*Significant difference—126.0 pounds; highly significant difference—176.9 pounds.

Thorogreen

The analysis of variance computed for the Erie County data relative to the Thorogreen variety indicated no significant differences among means of the various row spacing and plant spacing treatments, Table IV. Yields were particularly low at this location due to the late planting and unfavorable climatic conditions previously mentioned. The coefficients of variability being 27.9 and 29.8 per cent for row spacing and plant spacing analyses respectively, indicate also the desirability

TABLE VI—THE EFFECT OF VARIOUS ROW AND PLANT SPACINGS ON YIELD OF THOROGREEN LIMA BEANS (POUNDS PER ACRE OF SHELLED BEANS) CENTRE COUNTY, 1947

Width of Rows (Inches)	Spacing Within Rows (Inches)			Mean*
	4	8	16	
20	1,720	851	399	990
30	1,329	496	257	694
40	763	383	257	468
Mean†	1,271	577	304	—

*Significant difference—310.9 pounds.
†Significant difference—191.0 pounds; highly significant difference—268.1 pounds.
Interaction of width of row by spacing within row—significant difference—330.9 pounds.

of a larger test in order to reduce the error variance. Statistically reduced data from the trials at York also show no significant differences between means of the various row spacing treatments. Differences between means of spacings within rows are however highly significant and, as can be seen in Table V, each decrease in the plant spacing increment resulted in a highly significant increase in yield.

The F values of "row spacings", "plant spacings", and the interaction at Centre County, Table VI, were all significant. In each case the smallest spacing treatments produced the greatest yields. The significant interaction again indicates the differential expressions among the various spacing combinations.

COMBINED RESULTS

In Table VII are shown the yield results of all the various combinations of spacing treatments. The data have here been analyzed on the basis of a randomized block having three replications of nine treatments for each variety in each location. This facilitates a direct statistical comparison of all the treatments within each column of the table. A column of treatment means for all locations has been omitted because of lack of complete data for each combination. Extreme differ-

TABLE VII—YIELDS OF SHELLED LIMA BEANS AS INFLUENCED BY SPACING TREATMENTS AND LOCATIONS (POUNDS PER ACRE)

Spacing Arrangement (Inches)	Location and Soil Type					
	Erie Chenango Gravelly Sandy Loam		York Chester Gravelly Silty Loam		Centre Hagerstown Silty Clay	
	F*	T†	F*	T†	F*	T†
2×20	911	617	1,491	949	—	—
4×20	661	584	2,289	922	2,835	1,720
8×20	491	423	2,040	720	2,118	851
16×20	—	—	—	—	1,823	399
2×30	1,133	539	2,602	1,270	—	—
4×30	823	554	1,851	973	2,464	1,329
8×30	598	374	1,347	649	1,490	496
16×30	—	—	—	—	1,083	257
2×40	763	435	1,644	866	—	—
4×40	477	352	1,469	628	1,718	763
8×40	552	381	1,094	587	1,666	383
16×40	—	—	—	—	652	257
Required for significance 0.05	340.2	—	428.5	250.5	636.9	345.1
Required for significance 0.01	468.6	—	591.9	345.0	877.3	475.3

*Fordhook 242.
†Thorogreen.

ences in yields among the three locations might cause misinterpretation inasmuch as the weighting would be influenced by lack of data from any one location.

It is interesting to compare those plots in which areas per plant were equal but with different spacing arrangements. When plots 4 by 20 with 2 by 40 inches, 8 by 20 with 4 by 40 inches, and 16 by 20 with 8 by 40 inches are compared, it will be noted that those combinations having the narrower row and wider plant spacings were the more productive. This can be seen in Table VII. The only exception with either variety was obtained at Erie County in which Fordhook 242 at a spacing of 2 by 40 inches exceeded the yields obtained at a spacing of 4 by 20 inches. Apparently a plant spacing with approximately equal dimensions provides more desirable conditions for root spread and plant development than does a spacing with widely unequal dimensions. It is possible that drill row plantings of 8 by 8 up to 8 by 10 inches might result in greater yields than are now obtainable in wide row plantings. Such a development would be unlikely, however, until methods of pre-emergent control of weeds have been perfected, and until agricultural engineers have designed and developed new lima bean harvesting equipment.

Studies on spacing arrangements will be continued but modified to include varied soil fertilities in an effort to ascertain relationships between soil fertility and plant populations. Where moisture is not the limiting factor, increased yields of various crops by increasing soil fertility or plant populations, or both, have been reported (1, 4).

Summary

Large differences in mean yields were obtained at the various row spacings for the variety Fordhook 242. At all locations the plots with 40-inch rows were least productive. In Erie the 30-inch plots produced more than the 20, in York they appeared to be equal, and in Centre County the narrow rows produced the greater yields.

At all locations an inverse relationship existed between spacings within the rows and total yields per acre. This was true for Fordhook 242 and Thorogreen alike.

Although mean yields of the various row spacings of Thorogreen differed as much as 28 per cent in Erie and York counties the only statistically significant differences were obtained in Centre County, where the highest yield was produced on the 20-inch rows, the next high on the 30-inch rows, and the poorest yields at the widest row spacings.

The data indicate that plant spacings with equal dimensions are generally superior to spacings with equal area but with unequal dimensions.

Of the treatments studied a spacing of 30 by 2 inches was generally most productive for either variety under the soil and climatic conditions of the test areas.

In Centre County highest yields were obtained at a spacing of 20 by 4 inches; conditions however, prevented a comparison between the 20 by 2 and the 30 by 2 inch treatments.

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The Role of Snakehead Plants in Beans[1]

By E. V. HARDENBURG and W. H. ETO,[2] *Cornell University, Ithaca, N. Y.*

THE term "baldhead" or preferably "snakehead", has been loosely used to describe any abnormal seedling of the common bean *Phaseolus vulgaris* which has failed to develop both primary leaves and the terminal bud. In fact, the term has just as often been applied to similarly abnormal seedlings of lima beans. Snakeheads are most easily observed just after the seedling emerges and may in severe form exhibit only a bare stump of the epicotyl with no sign of either primary leaves or terminal bud. According to Harter and Zaumeyer (8), such a plant usually develops new shoots in the axils of the cotyledons, and a few flowers and pods may be produced. Snakeheads are caused mainly by injury to the embryo in threshing, by insects such as the bean maggot *Phorbia fusciceps* and by bacteria and fungi. Murphy (11) defines a snakehead bean plant as one resulting when the growing point of the new seedling is killed and one or both of the primary leaves have been detached from the stem. He reports that 1 to 3 per cent of snakeheads has been observed in Great Northern beans in his experimental plots in Idaho. Referring to injury by the seed corn maggot *Hylemyia cilicrura* Rondani, Burkholder and Crosby (3) define snakehead as a plant so injured that the bud between the two seed leaves of the bean seed is destroyed.

The germination of seed beans grown in the semi-arid regions of California and Idaho is often seriously reduced by thresher injury, especially after hot, dry weather. This type of injury usually resulting in snakehead plants is caused by a rupture of the embryo whereby the plumule is separated from the radicle at the node or point of attachment to the cotyledon. Harter (7) reported that snakeheads caused by fracture just below the plumule are incapable of further development. However, his illustrations of such plants show the development of axillary buds. He further stated that when the primary leaves are badly mutilated and the terminal bud destroyed by bacterial diseases, the epicotyl usually elongates and buds usually develop in the axils of the cotyledons. Harter showed that the snakehead character is not heritable, that it is more common in snap beans than in field beans, that it is associated with a relatively small diameter of the epicotyl and that it occurs more often in seed threshed with a machine than by hand. Thresher injury to seed of all types of lima beans was reported by Borthwick (2) and by Bainer and Borthwick (1) as a common cause of snakehead plants and that such injury could be largely avoided by proper equipment and operation of the threshing machine. Collins (5) in California studied the performance of snakehead plants grown from red kidney seed which had previously shown 15 per cent of this defect in the germination test. He made paired comparisons of 14 plants staked in the field about a week after emergence. Although the charac-

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ter of the snakehead plants was not stated, the decreases in number of pods, number of beans and weight of beans per plant were 51, 53 and 60 per cent respectively with high odds of significance.

During the normal life of the bean plant, no buds develop in the axils of the cotyledons. In an attempt to determine what factors produce this inhibitory effect, Moreland (10) by decapitating the plant at various heights above the cotyledons decided (a) that growing leaves have a more pronounced inhibiting effect on the development of the cotyledonary buds than does the apical bud, and (b) that the buds fail to develop because of a deficiency of some material, apparently nitrogen, which the growing top takes away from them. Chance (4), working with red kidney beans, studied the effect of wounding in various ways the primary leaf or leaves before the true leaves expanded. He wounded the leaves by removing discs, by removing various portions *en bloc*, and by slashing. The amount of leaf area removed was more important than the method of wounding and the removal of any portion tended to stimulate the rate of growth of the remaining portion. Although gross yield of the plant was not significantly reduced in any case, the blooming and maturity dates were delayed approximately in accordance with the amount of leaf tissue removed. Experiments to test the effects of pruning or partial defoliation of seedling plants have generally shown a retarded maturity and no increase in yield as a result. Kraus (9) recently reported such results from pruning transplants of several vegetables. Severe pruning reduced yields and retarded maturity of head lettuce, cauliflower, and celery while the yields of onion and pepper plants were not affected. He ascribed the reduced yields to a reduction in root formation and reduced ability of the plants to take water from the soil.

One of the few attempts to determine the field value of snakehead bean plants was made by Drake (6) at the Beltsville, Maryland Station. As a seed technologist, she defined a true snakehead as a seedling which "has no primary leaves and no terminal growing buds". From a total of 1970 seeds planted, 101 snakehead plants emerged and of these none had any primary leaves, while 23 had apparently intact terminal buds. About 32 per cent of the snakehead plants made no further growth, the remaining 68 per cent making various types of secondary growth. At the end of 68 days' growth when final measurements were made, all of the snakehead plants were very much retarded in growth and maturity as compared to the normal plants. Compared to the normal plants, the snakeheads with no primary leaves averaged per plant 81 per cent less weight of plant, 93 per cent less weight of pods, 83 per cent fewer pods, and 37 per cent shorter plants. Such data as these would indicate that seedlings with no primary leaves are of practically no value. To test the validity of this conclusion arrived at by several previous workers, the authors of this paper decided to test artifically produced snakehead bean plants under controlled conditions both in the greenhouse and in the field.

Plan of Greenhouse Experiment

California grown red kidney seed was used both for the greenhouse experiment in 1943 and for the field experiment in 1945. In the green-

house experiment, the seed was planted on June 16 in flats of four rows of 12 beans each, three replications of each treatment. Unfortunately, the plants were not thinned for uniformity of stand. To produce various types of snakehead seedlings, amputations of primary leaves and terminal buds in the axils of the primary leaves were made on June 22, a razor blade being used for this purpose. Counting the checks or unamputated plants as normal, there were six treatments as follows: 1, normal; 2, minus one primary leaf; 3, minus one primary leaf and terminal bud; 4, minus terminal bud; 5, minus both primary leaves; and 6, minus both primary leaves and terminal bud. Seedling plants were treated as soon as the plumule had spread sufficiently to expose the terminal bud. A sample plant of each treatment is shown in Fig. 1 and 2, the photographs being taken on June 30 or 8 days after the amputations.

Results of Greenhouse Experiment

Final measurements were made on October 5 after a growth period of about 110 days. The results are shown in Table I.

Lack of significance of the differences shown in Table I may be partially due to the variation in number of plants recorded for the various treatments. However, there is some indication that (a) removal of the terminal or apical bud (treatments 3, 4 and 6) results in the development of an increased number of pods per plant, and (b) removal of both primary leaves delays maturity of the pods and decreases yield. Although not a statistically significant difference, the

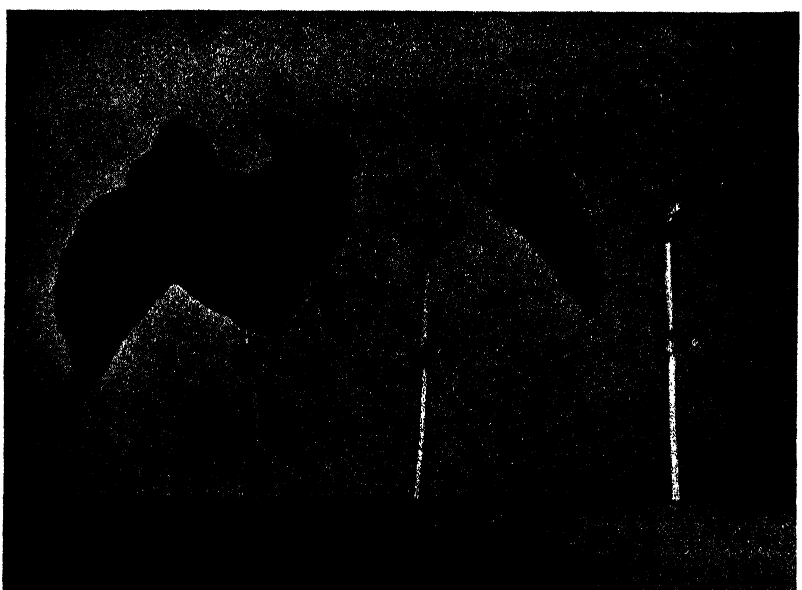

FIG. 1. Left to right — treatments: (1) Normal plant; (2) Minus one primary leaf; and (5) Minus both primary leaves.

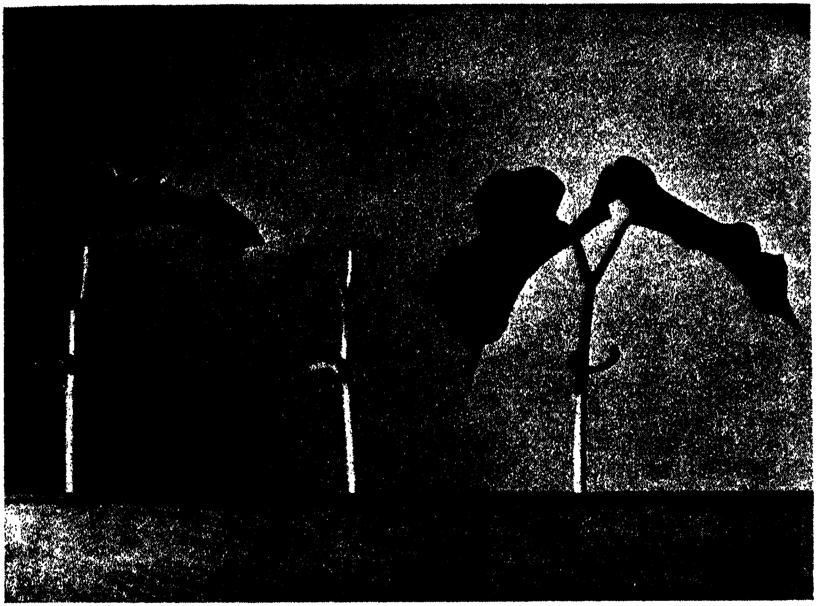

FIG. 2. Left to right — treatments: (3) Minus one primary leaf and terminal bud; and (6) Minus both primary leaves and terminal bud; (4) Minus terminal bud.

TABLE I—RELATION OF VARIOUS TYPES OF SNAKEHEAD PLANTS TO MATURITY AND YIELD OF RED KIDNEY BEANS (GREENHOUSE EXPERIMENT 1943)

Treatment Number	Treatment	Total No. of Plants	Pods Mature on October 5 (Per Cent)	No. of Pods Per Plant	Yield Mature Beans Per Plant (Grams)
1	Normal plant	99	68.1	2.77	4.13
2	Minus one primary leaf	82	68.3	2.82	4.36
3	Minus one primary leaf and terminal bud	88	67.4	3.06	4.92
4	Minus terminal bud	100	69.7	2.92	4.27
5	Minus both primary leaves	108	65.9	2.39	3.01
6	Minus both primary leaves and terminal bud	73	53.6	2.99	3.48
Significance of differences*			NS	NS	NS

*NS = Not significant at 5 per cent point.

number of stems per plant was highest for the plants minus the terminal bud. This may account for the higher pod set in these three treatments.

PLAN OF FIELD EXPERIMENT

In 1945 on Allis stony loam soil near Ithaca, New York, the role of snakehead bean plants was studied under field conditions. California

grown red kidney seed was again used. Planting was on June 8 in single row plots each 30 feet long, 28 inches apart. Treatments were in four replications and completely randomized. Rate of seeding was four plants per foot of row and although not thinned for stand, the stand appeared to be uniform. Amputation treatments identical with those used in the greenhouse experiment were made on June 19, while the plants were in the primary leaf stage and 11 days after seeding. All plants not as described for the respective treatments were eliminated, after which final stand counts were made. Extreme total variation in stand as between treatments was 8.8 per cent, the average final stand for all treatments being 76 per cent of the seed planted.

Results of Field Experiment

The experiment was harvested on September 20, or 104 days after planting. At that time the plants of all treatments except treatment 5 (minus both primary leaves) and treatment 6 (minus both primary leaves and terminal bud) were mature. Treatments 5 and 6 matured 2 to 3 days later than the others which fact corresponds with the results reported in Table I. The effects of the various amputation treatments obtained in the 1945 field experiment are shown in Table II.

TABLE II—Relation of Various Types of Snakehead Plants to Growth, Pod-Set, and Yield of Red Kidney Beans (Field Experiment 1945)

Treatment No.	Treatment	Total No. of Plants	Average Height of Plant 60 Days After Seeding (Inches)	No. of Pods Per Plant	Per Acre Yield of Beans (Bushels)
1	Normal plant	384	22	8.1 ±0.19	27.9
2	Minus one primary leaf	350	22	9.2 ±0.20	29.2
3	Minus one primary leaf and terminal bud	358	22	9.5 ±0.21	33.0
4	Minus terminal bud	354	22	9.0 ±0.18	28.8
5	Minus both primary leaves	365	17	7.5 ±0.16	24.8
6	Minus both primary leaves and terminal bud	376	14	7.2 ±0.17	19.8
L.D. for significance at 5 per cent point		—	—	1.0	3.5

Applying the least significant difference to the data for pod-set and yield, it appears that removal of the terminal bud alone did not significantly reduce either. It also appears that only when both primary leaves and the terminal bud (treatment 6) are destroyed is the yield significantly reduced. This exactly supports the definition of a true snakehead given by Drake (6) as a seedling which "has no primary leaves and no terminal growing buds". No explanation is offered for the apparent increase in pod-set and yield for treatment 3 where one primary leaf and the terminal bud were removed. Using the method of co-variance, where T refers to terminal bud and P refers to primary leaves, T by P interaction was not significant.

Discussion and Conclusions

It has been generally assumed that any malformation of the epicotyl of the bean seedling whereby all or part of its vegetative tissue is de-

stroyed constitutes a snakehead and that such a plant is of little or no economic value. Such assumption is based largely on the fact that the majority of such plants being delayed in development are later overshadowed by normal, healthy plants. Experiments with red kidney beans, both in the greenhouse and in the field were designed to simulate snakeheads by amputating at the primary leaf stage certain portions of the expanding plumule and the terminal bud. Plant height, pod-set, and yield were significantly reduced only when both primary leaves were removed. Though perhaps not significantly so, there is some evidence that removal of the terminal bud increases the number of stems per plant and the set of pods. Size of plants and rate of growth were reduced and time of maturity delayed by removal of both primary leaves. These facts were substantiated by observations made 21 days, 45 days and 60 days after seeding when plants in treatments 5 and 6 were distinctly smaller and carried smaller trifoliolate leaves. On June 25 in the field experiment about 17 days after planting, the cotyledons on the plants were well shrivelled except in treatments 5 and 6 where they were nearly all plump and somewhat greened.

From the results of these two experiments, the following conclusions seem justified:

(1) Of the various types of snakehead seedlings in beans, only that involving the loss of both primary leaves is sufficient to cause a significant loss of yield.

(2) Loss of the terminal bud does not affect yield but apparently such loss does tend to facilitate the development of axillary buds when its "dominance" is removed. This tends to increase stem number and pod-set.

(3) The primary leaves are especially important in the early growth of the plant as they enhance development of the root system, draw nutrients from the seed cotyledons and stimulate growth of the terminal bud or buds.

(4) Loss of one primary leaf is unimportant because apparently the loss is compensated by an accelerated growth of the remaining vegetative tissue as found by Chance (4).

(5) True snakehead plants, those involving loss of both primary leaves, mature a few days later than other types especially when the loss is accompanied by destruction of the terminal bud.

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Preliminary Notes on Frost Prevention Under Cold Frame Glass by Sprinkling the Glass with Cold Water[1]

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It is not an uncommon practice to utilize a cold water spray or sprinkle to protect crops from injury by light frost, but the practice has not been adapted to frost prevention under glass as far as the writer can ascertain. The conventional methods of frost prevention such as covering the sash with mats or straw involve a considerable labor cost as well as the uncertainty of frost prevention on windy nights. Some growers in New York State are maintaining above freezing temperatures under glass on cold nights by the use of electrical resistance wires.

The purpose of the study reported here was to determine if a cold water spray or sprinkle, directed on the upper surface of the cold frame sash, could be depended upon to prevent plants from freezing under the glass.

Materials and Methods

On February 25, 1947, two adjoining, five-sash frames, which had been open to the climate all winter were covered with a single layer of glazed sash. These frames were of the usual 2-inch plank construction with the south wall of the frames 6 inches lower than the north wall. Each frame was 6 feet by 15 feet with the bottom of the enclosure 4 inches below the surrounding ground level. None of the walls was banked, either inside or outside of the frames, because a test of very extreme conditions was desired.

A ¾-inch pipe spray boom was equipped with four No. 3 spray nozzles, and one No. 46 Monarch fan nozzle, spaced so that the spray from each nozzle fell at the top center of its respective sash, as illustrated in Fig. 1. The fan nozzle is the second from the left. This boom of nozzles was attached to the faucet of a stand pipe which was normally used for watering plants in this section of cold frames. A galvanized iron trough was attached to the lower wall of the frame to conduct the water away after it had passed down over the glass.

Temperature readings in degrees Fahrenheit were taken in each frame from a minimum-maximum thermometer, two double scale thermometers, and a thermograph. The double scale thermometers were inserted through holes bored in the plank wall so that one gave a reading at a point 1.5 inches below the glass at the lower end of the sash, and the other a reading at a point 1 inch below the glass at the upper end of the sash. The minimum-maximum thermometer in each frame was suspended directly from the center of the middle sash. Outside temperatures were taken also from the standard minimum-maximum thermometers.

During the trial run of March 12 and 13, there were no plants under the glass in either frame and no mats were placed over the check frame

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FIG. 1. Appearance of sprinkled frame after operating through a 19 degrees F minimum night temperature. Fan nozzle in use over second frame.

sash. After this test of sprinkled sash versus unprotected glass, the check frame was covered with single or double bamboo mats, according to the weather expected for the night. Six potted tomato plants, some of which were tall enough to touch the under side of the glass, were placed in each of the two frames following the trial run.

The experiment was started on March 12, 1947, and continued in operation until April 17. The trial run began at 2 p m on March 12 and ended at 10 a m on March 13. The weather for this period was cool and clear until midnight of the 12th, at which time the sky became overcast with clouds.

RESULTS

During the trial run, the outside air temperature dropped steadily from 44 degrees F at 4 p m to 16 degrees F at 12 midnight, and then rose gradually to 23 degrees F at sunrise 6:40 a m. At 9 p m, the temperature under glass in both frames was 35 degrees F and the outside temperature was 25 degrees F. The sprinkler was opened at this time at a rate to deliver 6 gallons per sash per hour. The water temperature at the nozzle varied from 45 degrees to 47 degrees F. At midnight, the minimum temperature under glass was 36 degrees F.

In the check frame conditions were quite different. At 9:30 p m the outside temperature was 23 degrees F and the inside temperature was 32 degrees F, while at midnight the inside temperature had dropped to

17 degrees F. Some water accumulated in the bottom of both the check and the sprinkled frames as a result of inadequate drainage away from the sprinkled frame and poorly glazed sash. This fact may have accounted for some protection afforded the sprinkled frame since the check frame remained 1 degree F above outside air temperature.

During the 37 consecutive nights that the records were taken, there were 21 nights with temperatures below 32 degrees F, 8 nights with temperatures below 20 degrees F, and 2 with minimum readings of 12 degrees F. The data gathered on the night of March 17–18 are presented in Table I.

TABLE I—RECORD OF TEMPERATURE UNDER SPRINKLED GLASS SASH VERSUS GLASS SASH COVERED WITH DOUBLE BAMBOO MATS

Time March 17 and 18, 1947	Air Temperature Under Glass (Degrees F)				
	Outside Temperature (Degrees F)	Sprinkled		Check	
		Lower	Upper	Lower	Upper
4:45 pm, mats put on sash	27	39	41	44	44
5:15 pm	27	39	40	44	44
5:30 pm	26	38	39	43	43
5:45 pm	25	36	37	42	42.5
6:00 pm, water turned on sash	25	34	36	42	41
6:15 pm	23	37	37	42	41
6:30 pm	23	37	37	42	41
7:30 pm	22	33	33	38	39
7:45 pm	22	34	34	38	39
8:00 pm	22	34	34.5	38	39
8:15 pm	22	34	34.5	38	38.5
8:30 pm	21.5	34	34.5	37.5	37.5
9:00 pm	21.5	34	34.5	37	37.5
9:30 pm	21	34	34.5	36	37
10:00 pm	21	33.5	34.5	35	36
10:30 pm	21	33	34	35	35
11:00 pm	21	33	33	34.5	34.5
11:30 pm	20	33	33	34	34.5
12:00 m	22	33	33	33.5	34
1:00 am	21	33	33	33	33.5
2:00 am	20	33	33	32.5	33
3:00 am	20	32.5	33	32	32.5
3:30 am	20	32.5	33	32	32.5
4:00 am	19	32	33	31.5	32
4:30 am, freezing in check frame	20	32	33	31	31.5
5:00 am	21	32.5	33	31	31.5
8:00 am	28	36	37	31	31
9:30 am	32	41	42	32	32

The check frame was covered at 4:45 p m with double mats. The sprinkler was turned on at 6:00 p m to deliver 4.25 gallons of water per sash per hour. It will be noted from Table I that the outside temperature continued to drop after the water was turned on, and it is also evident that the 4.25 gallon rate of flow was insufficient to maintain a constant temperature under glass, consequently, the rate of flow was increased at 7:30 p m to 5 gallons of water per sash per hour. No further adjustments were made.

The fluctuations in the outside temperature recorded in column 1 were a result of snow flurries and variable winds. The data in columns 2 and 3 show that it was usually a little cooler under glass along the lower side of the frame. A slight reversal of this condition is shown in columns 4 and 5 for a half-hour period from 6 to 6:30 p m.

The minimum temperature under the glass in the sprinkled frame dropped to 32 degrees F at 4 a m and a few leaves of tomato plants

resting against the glass showed frost injury. In the check frame the temperature dropped to 31 degrees F at 4:30 a m and remained at that temperature until after 8 a m. Frost injury was not limited to the leaves resting against the glass, however, only one plant was killed.

Fig. 1 illustrates the condition of the sprinkled frame at 9:30 a m following the gathering of the data in Table I. It will be observed that the fan-type delivery on the second sash was far superior to the cone-type sprinkle being delivered on the first sash. This is due mainly to the fact that most of the water from the fan-type nozzle strikes the glass at a very short distance from the aperture and yet gives the wide angle coverage necessary for tempering each run of glass in a sash.

Discussion and Summary

In judging the value of this method of frost prevention from this preliminary study, several factors must be considered. First, the operation was performed earlier in the spring than growers would normally use their cold frames in western New York; second, the system was manually operated with equipment not particularly designed for the job; third, the effect on subsequent crop performance after subjecting it to lower average night temperatures and a longer photo-period has not been investigated.

For a large scale operation, there must be an ample supply of water and provisions for disposition of the run-off, although a closed system could be used to obviate this situation. The entire system could be automatically controlled through the use of a solenoid valve and an air bulb thermostat.

No difficulty was experienced with pipes freezing, but an automatic drain valve would seem practical, since the outside temperature generally dropped to 25 degrees F before the under-glass temperatures approached the critical point. When the water was turned on before the inside temperatures dropped of their own accord to the temperature of the water or below, the flow of water over the glass reduced the inside temperature rather rapidly. This apparent undesirable feature might be capitalized upon in the process of cooling the frames, during short periods of high solar radiation. It is essential that the sash have at least a 4-inch slope in 6 feet and be well glazed in order to prevent leakage into the frame.

In summarizing the results of this preliminary study, it can be safely stated that a well distributed flow of 5 gallons of water per hour per sash will give more protection to plants under glass than a double layer of bamboo mats.

The Effect of Some Weed Control Practices on the Yield and Keeping Quality of Onions[1]

By William E. Chappell, *University of Connecticut, Storrs, Conn.*

The largest single item of expense in the production of onions on most farms is weed eradication. At present practically all the weeding is done by hand and some growers spend as much as $100 an acre for this operation. Various other weed control measures have been used experimentally on onions but few are suitable for practical usage. Any inexpensive material that will cut down the number of weeds and not result in a lowering of the yield or keeping quality would be of considerable economic importance to the grower.

In the experiments reported here some of the materials used had not been used before for weed control in onions but most of them had been tried at other places with varying results. Studies were made on the effects of materials on yield and keeping quality applied at two stages of growth: (a) post-emergence, and (b) pre-harvest.

Many chemicals have been used in seeking a selective weed killer for onions. One that has shown some promise is a weak solution of sulphuric acid. Newhall (2) carried on extensive tests with sulphuric acid on onions that were 4 to 6 inches high. He found that the most effective concentration from the standpoint of killing a maximum number of weeds without much injury to the onions was a 2 per cent (by weight) solution at 100 gallons per acre. Two of the more common weeds on the muck soil, *Portulaca oleracea* (purslane) and *Chenopodium album* (lamb's quarters) were not reduced significantly. Grasses were also very tolerant to the acid. The total number of weeds was reduced significantly without a significant loss in yield. He noted that either brass, copper or lead coated tanks should be used with this treatment. In comparison with other chemicals, such as cyanamid dust, sinox (Na dinitro-ortho-cresylate), sodium chlorate, and Fe_2SO_4, sulphuric acid caused a minimum amount of injury to onions with the greatest number of weeds killed.

Ball and French (1) used a 10 per cent (by weight) solution of H_2SO_4 on onions infested with knot grass *(Polygonum aviculare)*. They reported severe burning of the onion leaves at first but recovery was soon made and there was no visible difference between the treated and untreated plots. No yield data were given.

Warren (3) tried various chemicals as weed killers on onions and other vegetables. Sodium chloride applied as a 25 per cent solution at 100 gallons per acre reduced yield significantly in one location, but not at another and reduced the number of weeds significantly. H_2SO_4 applied as a 2 or 3 per cent solution (by volume) at 100 gallons per acre did not significantly reduce the yields of onions and gave good control of some weeds. Other chemicals, such as Stoddard solvent,

[1]Part II of a thesis presented to the Graduate School of Cornell University in partial fulfillment of the requirement for the degree of Doctor of Philosophy, September 1947.

2,4–D, 1 : 1000, Sinox 1 : 100, and G506 (ammonium salt of dinitro-ortho-secondary butyl phenol) 1 : 200 were very toxic to onions.

Methods

During the summer of 1946 various weed control materials were applied to onions at two stages of growth: (a) post-emergence treatments to onions about 8 weeks old, and (b) pre-harvest treatments when the plants were mature.

Since the experiments at the two stages of growth were somewhat different, the methods used will be presented separately along with the results obtained.

Results

Post-Emergence Treatments:—Several preliminary tests were conducted with various materials. The best of them were selected and applied as follows:

1. 2 per cent H_2SO_4 at 100 gallons per acre
2. 20 per cent NaCl at 100 gallons per acre
3. Cyanamid at 50 pounds per acre in H_2O suspension
4. Cyanamid dust at 50 pounds per acre
5. Check (weeds pulled by hand)

At the time of application the onions were 6 to 8 inches high and had several true leaves. The weeds were mostly redroot, purslane and chickweed, all of which were about as tall as the onions. On the day the applications were made the temperature was 60 degrees F and the humidity 70 per cent. The plots were 10 feet by 10 feet and each treatment was replicated four times. At the time of application of the materials there was an average of 120 weeds per 10 feet of row. The plots were cultivated three times during the growing season.

Some of the materials caused considerable injury to the onion plants. Calcium cyanamid dust applied at 50 pounds per acre caused the most severe burning of the onion leaves; sulphuric acid, calcium cyanamid spray and sodium chloride resulted in less injury in the order named. Scarcely any injury resulted from the sodium chloride application. Within 3 weeks after application the plants seemed to have recovered fully and there were no apparent differences in the appearance of the plots.

The number of weeds was reduced by all the materials used in this experiment, but there was no significant difference between any two.

On August 20, the onions from each plot were counted and weighed. A 200-bulb sample of U. S. No. 1's from each plot was kept for storage to study possible effect on keeping quality. There was no significant difference in the number or weight of bulbs from any of the treatments. Neither was there any effect on the amount of sprouting in storage. There was not more than 1 per cent decay in any of the samples and this was not considered enough to justify an analysis on that basis.

Pre-harvest Treatments:—In an attempt to find a suitable weed killer to apply to mature onions the materials listed in Table II were used on 10 feet by 10 feet plots and each treatment replicated four times.

TABLE I—EFFECT OF APPLICATION OF WEED CONTROL MATERIALS AS TO GROWING ONIONS ON YIELD AND SUBSEQUENT SPROUTING IN ONIONS (YIELD, POUNDS PER PLOT; SPROUTS, PER CENT OF 200 BULBS STORED 4 MONTHS)

Treatment	Yield (Pounds)	Sprouts (Per Cent)
1. 2 per cent H_2SO_4 at 100 gallons per acre	45.18	14.25
2. 20 per cent NaCl at 100 gallons per acre	49.15	12.54
3. Cyanamid at 50 pounds per acre (H_2O suspension)	48.5	11.25
4. Cyanamid at 50 pounds per acre (dust)	45.56	12.75
5. Check (hand weeded)	49.81	14.38
L. S. D.	N. S.	N. S.

TABLE II—EFFECT OF APPLICATION OF WEED CONTROL MATERIALS AS A PRE-HARVEST TREATMENT ON THE YIELD AND KEEPING QUALITY OF ONIONS

Treatment	Yield (Pounds)	Sprouts (Per Cent)	Decay (Per Cent)
1. Dow Herbicide 3 per cent at 100 gallons per acre	46.69	4.84	1.40
2. Dow 66 3 per cent at 100 gallons per acre	48.63	4.10	1.70
3. Sovasol No. 5 at 100 gallons per acre	43.00	4.70	1.30
4. Solvesso No. 3 at 100 gallons per acre	48.00	6.70	2.60
5. Sovasol No. 75 at 100 gallons per acre	47.56	6.50	1.65
6. Check	47.33	5.90	1.60
L. S. D.	N. S.	N. S.	N. S.

The treatments were given 10 days before harvest. At the time of application weeds and grass practically covered the ground. After harvest the onions were placed in common storage for a period of 4 months. At the end of this period the bulbs were examined for decay and sprouts.

All the materials used killed the weeds and grasses in the plots on which they were applied with the exception of Dow 66 Improved. This did not cause any apparent injury to the onion tops and grasses were not killed.

There was no difference in the fresh weights of bulbs from the treatments as shown in Table II. After storage the bulbs were sorted and the number of sprouted and decayed ones recorded. None of the materials applied caused any significant differences in sprouting or decay, as compared to the check, of the stored bulbs.

SUMMARY AND DISCUSSION

The fact of all the materials used in the post-emergence experiment reported here gave a fair control of weeds without reducing the yield is probably due to the species of weeds found at that location. Seventy-five per cent of the weeds were chickweed *(Stellaria media)* and red-root *(Amoranthus refroflexus)* both of which are easily killed. There was very little grass, purslane *(Portulaca oleracea)* or lamb's quarters *(Chenopodium album)* present.

The use of sodium chloride in a 20 per cent solution at 100 gallons per acre would deposit 200 pounds per acre in the surface layer of soil. Such an amount would not be harmful in one application, but after

continuous usage over a period of years could easily build up to toxic proportions in the soil.

Calcium cyanamid at 50 pounds per acre would probably have little toxic effect on the soil as it would change over to form available nitrogen soon after application. It is necessary to apply cyanamid dust to weeds when they are moist, either early in the morning when the dew is on or after a rain so that it will stick to the leaves. In either case, the onions are damp and considerable injury occurs to them. The amount of injury by cyanamid was greater than any of the other materials used but not enough to reduce yields with one application. When applied as a suspension in water about the same effect was found as in the dust form but it would require much more labor in application.

Sulphuric acid in a 2 per cent solution killed more weeds than the other materials but not significantly so. Newhall (2) reported similar results with sulphuric acid. Special equipment must be used with this material such as lead or copper tanks on sprayers and must be handled with extreme care to prevent personal injury.

Selective weed killers in onions offer good possibilities in eliminating hand weeding as the present work indicates but more work must be done. Some new materials seem to be much better selective weed killers for onions than any previously used.

None of the materials used in this experiment affected the keeping quality of the stored onions.

Very toxic materials, such as used in the pre-harvest experiment killed all weeds and onion tops with no apparent injury to the bulbs. After 4 months in storage there were practically no decayed bulbs from any of the treatments.

A pre-harvest treatment would be unnecessary on many farms that are not bothered with weeds late in the season. On other farms where weeds completely cover the ground soon after the onion tops are down, pre-harvest treatment should prove of considerable value.

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Chemical Weed Control in Onions (Preliminary Paper)[1]

By W. A. Hedlin, *Cornell University, Ithaca, N. Y.*

The weed problem with onions starts at seeding time and may persist through harvest, causing one of the heavier expense items in connection with the production of this crop. There are three distinct phases of weed control work in onions. The first is dealing with weeds before they emerge from the ground (pre-emergence weed control), the second is with weeds in seedling onions when they may be as large or larger than the onions (post-emergence weed control), and the third is with weeds in well grown onions (also referred to as post-emergence weed control). Occasionally there is also a weed problem at harvest time but this may be eliminated if the earlier weed control is achieved. This paper deals with pre- and post-emergence weed control and also work done with a new selective herbicide in onions.

The experiments were conducted on muck soil in the area at Elba, New York. The weed population consisted mainly of purslane *(Portulaca oleracea)*, crab grass *(Digitaria sanguinalis)*, pigweed *(Amaranthus retroflexus)* and lamb's quarters *(Chenopodium alba)*.

Pre- and Post-Emergence Weed Control with the Compound Calcium Cyanamide ($CaCN_2$)

Work done by Dr. W. E. Chappell[2] in the summer of 1946 indicated that calcium cyanamide might give satisfactory results as a pre-emergence weed control treatment for onions. In 1947 experiments were set up to continue this work and also to determine the effect of post-emergence treatments.

Calcium cyanamide was applied as a dust on plots 10 feet by 20 feet with a hand duster, using four replications. The seed was sown on April 28 and 5 days later all plots received either 100 or 200 pounds per acre as a pre-emergence treatment. At this time there was no growth on any of the plots. The onions on the untreated plots emerged on May 15 and were from 24 to 48 hours later in emerging on the treated plots. On May 15, during emergence, plot number eight received a second application at the rate of 50 pounds per acre. On May 22 all plots except numbers 1 and 2 received a further treatment of 50 or 100 pounds per acre of calcium cyanamide. Counts of weeds and onions are the means of five samples from the row, each 3 feet long and 2 inches wide, except for harvest data which included the whole plot.

Pre-emergence alone reduced the weed population by 50 per cent, but better results were obtained with an added post-emergence treatment. The latter procedure eliminated about nine-tenths of the early hand weeding.

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[1]Paper No. 291, Department of Vegetable Crops, Cornell University, Ithaca, N. Y.

[2]Now at the University of Connecticut, Storrs, Connecticut. The author is indebted to the American Cyanamid Company for supplying the materials used.

TABLE I—EFFECT OF PRE-EMERGENCE ALONE AND WITH ADDED POST-EMERGENCE TREATMENTS OF CALCIUM CYANAMIDE AT RATES INDICATED ON NUMBER OF WEEDS AND ONIONS BY MAY 26

Treatments			Weeds Per 0.5 Sq Ft May 26	Onions 3 Feet of Row May 26
Pre-Emergence May 3	Post-Emergence May 15	Post-Emergence May 22		
1 Untreated	—	—	118.75	23.25
2 100	—	—	59.00	23.50
3 100	—	50	10.75	23.75
4 100	—	100	12.75	22.75
5 100	—	50	12.25	24.00
6 100	—	100	14.50	24.75
7 100	—	50	10.50	22.00
8 100	50	50	13.75	23.25
9 200	—	50	27.75	23.50
L.S.D. .05..........			14.48	2.40
.01.........			19.93	3.21

EFFECTS OF FURTHER POST–EMERGENCE TREATMENTS OF CALCIUM CYANAMIDE

The original plots described in Table I were all hand weeded on May 27 and plots 5 to 9 inclusive received a further application of 50 or 100 pounds per acre of calcium cyanamide. On June 6 counts were again made. It is apparent (Table II) that a large number of weeds were killed by the later application of dust, and that there was no significant effect on the onion stand at this stage.

TABLE II—EFFECT OF THE INDICATED PRE- AND POST-EMERGENCE TREATMENTS OF CALCIUM CYANAMIDE AT LAST WEED COUNT (JUNE 6) AND AT HARVEST

Treatments				Second Count		Harvest (Aug 26)	
Pre-Emergence May 3	Post-Emergence May 16	Post-Emergence May 22	Post-Emergence May 27	Weeds Per 0.5 Sq Ft Jun 6	Onions Per 3 Feet of Row Jun 6	Onions Per Plot	Yield Lbs Per Plot
1 Untreated	—	—	—	27.00	15.25	331.0	55.60
2 100	—	—	—	21.75	18.25	355.0	59.90
3 100	—	50	—	8.75	13.00	256.0	43.25
4 100	—	100	—	8.75	14.00	206.0	34.50
5 100	—	50	50	13.25	16.50	242.0	42.60
6 100	—	100	100	8.50	12.75	219.0	30.10
7 100	—	50	50	12.25	12.75	249.0	35.75
8 100	50	50	50	10.25	13.00	240.0	40.00
9 200	—	50	50	13.25	14.50	271.0	41.40
L.S.D. .05.....				9.80	3.40	69.97	12.50
.01.....				13.28	4.60	94.98	16.94

It can be seen that the residual effect on the 100 pounds per acre as pre-emergence treatment had been largely dissipated as there was no longer a significant difference between the check and 100 pounds pre-emergence treatment. A portion of the loss in stand of onions between Table I and II, noticeable also in the untreated plots, was due to maggots.

Where pre-emergence treatments of 100 pounds per acre of calcium cyanamide had been applied, post-emergence treatments significantly reduced the yield.

Some Observations on Large Scale Application of Calcium Cyanamide for Pre- and Post-Emergence Weed Control

About 150 acres were dusted by airplane in the Elba area in the spring of 1947 at a rate of 50 to 75 pounds per acre. The results of this work clearly indicated that 75 pounds is adequate for pre-emergence weed control. Some striking results were obtained when calcium cyanamide dust was used as a post-emergence weed control treatment at a rate of 50 pounds per acre on very weedy seedling onions. The material was applied when the plants were wet with dew. The seedling onions suffered very little damage from this treatment though all small broadleaved weeds were dead within 48 hours.

Potassium Cyanate as a Selective Herbicide for Onions

In the pre- and post-emergence work with calcium cyanamide it was observed that little control of purslane, which usually germinates later in the season, was obtained. In searching for a compound to control this weed, preliminary studies suggested that potassium cyanate (KOCN) might give good results. Hence, in the spring of 1947 experiments were set up to determine the value of this chemical for weed control in onions together with the interrelationship between weed control and crop injury.

In all cases sprays were applied, at a rate of approximately 80 gallons per acre, with a knapsack sprayer on plots 10 feet square. Weed and onion counts were taken over each entire plot, the only weeds being those too close to the onions to be taken out by cultivation.

TABLE III—Weed Survival in Seedling Onions Following Treatment with Indicated Concentration of KOCN

Concentration	Grass	Purslane	Lamb's quarters	Pigweed	Totals
Untreated	44.5	31.5	9.0	18.5	103.5
0.5 per cent	15.5	10.0	3.5	7.0	31.0
1.0 per cent	9.0	4.0	0.0	0.5	13.5
L.S.D. .05					10.97
.01					25.31

The weather at the time of application was hot and dry. In no case was a satisfactory result obtained with KOCN when the plants were wet, though wet ground was no liability.

The susceptibility of the different weeds to KOCN is indicated in Table III. Crab grass will not usually be killed unless very small at the time of spraying. Purslane was readily killed by low concentrations up to the time it had developed fleshy stems so it should be sprayed before the rosettes exceed 1 inch in diameter. This is particularly important when using low concentrations for seedling onions. Lamb's quarters and pigweed were both killed very readily when small, the former becoming much more difficult to kill as it grows larger.

In dealing with weeds in larger onions (Table IV) stronger solutions may be used, especially when the spray is directed "low". The spray in this experiment was directed "high" to cover weeds and onions indiscriminately or "low" so as to hit only the basal portion of the onion plant. The field had been weeded about 10 days previous to

the first spray so there were no large weeds present. The results obtained are indicated in Table IV.

TABLE IV—THE EFFECT OF KOCN ON NUMBER OF WEEDS AND YIELD OF ONIONS PER 100 SQUARE FEET IN CULTIVATED PLOTS

Treatment	Weed Count				Harvest—Aug 29	
	Jul 4 After Spraying Jun 26	Jul 29 Before Spraying Jul 30	Aug 11 After Spraying Jul 30	Total Weeds Pulled Throughout Season	No. of Onions	Yield (Pounds)
1 Untreated	25.50	55.85	63.50	88.00	211.50	31.00
2 1 per cent	5.25 (low)	43.50	6.00	11.25	216.75	31.00
3 1 per cent	8.00 (high)	38.00	6.00	14.00	193.50	26.00
4 2 per cent	1.50 (low)	48.25	4.25	5.75	213.75	26.75
5 2 per cent	2.50 (high)	43.75	1.75	4.25	238.75	27.50
6 3 per cent	0.25 (low)	48.75	4.25	4.50	196.00	25.50
7 3 per cent	0.75 (high)	55.25	1.75	2.50	236.25	26.50
8 4 per cent	0.00 (low)	51.50	52.75*	52.75	243.25	30.50
L.S.D. .05		14.60	14.41	17.70	54.36	8.28
.01		19.87	19.62	24.83	72.73	11.26

*This plot was not sprayed July 30.

When a 3 per cent spray was used "high" a slight curling was noted on the onions. This disappeared within 48 hours and was the only visible effect on the crop. The weed count on July 29, just before the second spraying, indicates that there was no residual effect on the weeds from this compound since the treated plots grew as heavy a second crop of weeds as the checks. When the second spray was applied on July 30 it was all "low" since the top growth of onions was large enough to protect the weeds from a general spray. As far as the weed kill is concerned, there does not seem to be a valid reason for going above 2 per cent, provided the weeds are still very small when the application is made. There was no effect on yield or number of onions between the "high" and "low" applications.

SOME OBSERVATIONS ON LARGE SCALE APPLICATIONS OF POTASSIUM CYANATE AS A SELECTIVE HERBICIDE IN ONIONS

Mr. Bernard Berglin of Elba treated 5 acres of onions three times, starting on June 24, when the onions were about 1-foot high. His first two applications were 2 per cent solutions and the third a 3 per cent solution. All sprays were "low", applied at 80 gallons per acre. By this means he eliminated two hand weedings. Untreated areas were maintained in the field throughout the season and these showed no difference in yield.

SUMMARY

Calcium cyanamide, applied at 75 pounds per acre, was effective as a pre-emergence weed control treatment for onions. Also it was very effective as a post-emergence treatment when applied at 50 pounds per acre on weeds wet with dew.

These studies further indicate that potassium cyanate (KOCN) was a selective weedicide for onions if low (1 per cent) concentrations were used while the onions and weeds were very small. With larger onions a 2 per cent solution was more effective but the weeds must still be small when treated.

Varietal Response of Sweet Corn to 2,4–D Spray, and the Effect of Different Formulations of 2,4–D on Yield

By N. K. Ellis and E. T. Bullard, *Purdue University, Lafayette, Ind.*

The varying effects on yield, reported for application of sprays of 2,4–dichlorophenoxyacetic acid (2,4–D) on sweet corn for the control of weeds indicated that other facors than the effect of the acid might enter into the response. Shafer *et al* (2) found that 2,4–D is relatively harmless to corn plants 8 to 10 inches high, but that it could injure large corn plants if sprayed directly into the tops of the plants. Warren *et al* (3) found that 8 pounds of 2,4–D per acre applied before planting time and at planting time delayed maturity in Golden Cross Bantam sweet corn. They also found a reduction in stand when 8 pounds of 2,4–D was applied per acre at planting time.

Hoffman (1) reported a reduction in corn yield in one instance from the use of ½ pound of 2,4–D per acre and a 50 per cent increase in growth in another instance when applied at the rate of 1½ pounds per acre. Hoffman (1) also observed that plants treated with 2,4–D had distorted and fasciated brace roots. He also found a difference in varieties in the brittleness of stalks when the plants were treated with 2,4–D.

This is a preliminary report on one year's results with 2,4–D. The experiments reported in this paper were designed to determine (a) whether different varieties of sweet corn responded differently to 2,4–D treatments and (b) whether the several formulations of 2,4–D on the market might produce different results with Golden Cross Bantam sweet corn.

Materials and Methods

Two separate experiments were run. The first was a varietal response test including 18 different varieties of sweet corn; the second experiment was set up to test five formulations of 2,4–D on one variety.

For the first of these two experiments the 18 varieties, listed in Table I, were planted by hand on June 12, 1047. The rows were spaced 3 feet apart with three kernels planted in hills 3 feet apart in the row. An application of 600 pounds of 3–12–12 fertilizer was applied to the plots 1 week before the corn was planted. The soil was Fox silt loam of low fertility. A split plot design was used consisting of 18 paired plots 30 feet long. The paired plots were randomized in each of four blocks. One row of each paired plot was sprayed with 70 per cent sodium salt of 2,4–D, at the rate of .7 pound 2,4–D acid per acre, in 100 gallons of water, while the other row was used as a check. The treatments were applied July 22, when the plants were 15 to 18 inches high. A power sprayer fitted with a nozzle designed to produce a fan-shaped spray was used. The spray was directed toward the base of the plant, covering an area 10 inches wide on either side of the row. Spraying of the leaves was avoided as much as possible and because of the

low pressure (30 pounds), there was no appreciable amount of drift. Two border rows were used on each side of the four blocks. The corn had been cultivated twice previous to spraying, but no hand hoeing was done.

In the second test in which five formulations of 2,4–D were used on one variety of sweet corn, shown in Table II, 300 pounds of 3–12–12 fertilizer was applied to the plots 1 week before planting, and another 300 pounds of 3–12–12 fertilizer applied at planting time. The seed was planted June 12 with a standard two-row corn planter set for 3-foot rows. The planter was adjusted so that it would drop approximately one kernel every 12 inches. Each plot consisted of two 30-foot rows. Dosage of all 2,4–D materials used are expressed in terms of 2,4–D acid or acid equivalent per acre. The treatments were applied with the power sprayer already described. Ten randomized replications of each treatment were used. The plants received two mechanical cultivations previous to the spray, but did not receive any hand hoeing. Care was exercised to avoid contamination of the sprayer between treatments.

Observations and Results

Varietal Response:—The one application of 2,4–D gave good control of all the weeds present, the most prevalent weed being Indian Mallow *(Abutilon theophrasti)*. One week after the spray was applied a wind and rain storm occurred. Many of the corn plants were broken, and some varieties appeared to be affected more than others. The type of breakage was a clean break through the first node above the soil surface. The varieties which showed little injury and breakage were Illinois 10, Tendermost, and KNF 45. The total stand of these varieties were greater than the check plots, but they were not significantly higher. The varieties which showed the most injury and breakage were Country Gentlemen, White hybrid 3321, and Huron. The total stand of these varieties was below that of the check plots, but was not significantly lower. Many of the varieties showed distorted and fasciated brace roots; others produced an increased number of feeder roots as shown in Fig. 1. The variety Erie was the most outstanding in this respect.

Records were taken on stand, number of marketable ears, and weight of marketable ears with the husks on as shown in Table I. There did not seem to be any difference in maturity between the treated and untreated plots. All replications of the same variety including checks were harvested at the same time.

There was no significant difference between the check and treated plots on the basis of stand, yield, or the number of marketable ears. There was a significant difference at the 1 per cent level between varieties for stand, yield, and the number of marketable ears. There was no significance for interaction between variety and treatment on the basis of stand, yield, or number of marketable ears at the 5 per cent level.

Effect of Formulation:—The Golden Cross Bantam sweet corn treated with the butyl ester of 2,4–D showed a rolling of the younger

FIG. 1. Roots of Erie sweet corn. Left: sprayed with 2,4-D. Right: control. Note fasciated brace roots and feeder roots on treated plants.

TABLE I—EFFECT OF 2,4-D ON NUMBER OF EARS, STAND, AND YIELD ON 18 DIFFERENT VARIETIES OF SWEET CORN

Varieties	Date Harvested	Stand (Number of Stalks Per Acre)		Number of Marketable Ears (Dozens Per Acre)		Weight of Marketable Ears (Tons Per Acre)	
		2,4-D	Check	2,4-D	Check	2,4-D	Check
Silver Cross	Sep 1	8,228	7,018	484.0	413.4	1.55	1.49
Country Gentlemen	Sep 11	10,527	11,737	675.5	566.3	2.10	2.28
Illinois 8 and Illinois 6	Sep 11	11,495	11,495	665.5	776.4	2.30	2.52
White Kernel Golden Cross	Sep 4	9,196	10,043	554.4	675.6	1.93	2.31
White Hybrid 3321	Sep 11	13,068	13,431	746.2	867.1	2.49	2.72
Illinois 10	Sep 11	12,826	12,705	887.3	756.3	2.80	2.43
Narrow Grain Evergreen	Sep 11	7,986	9,075	423.5	605.0	1.83	2.54
Keyston Evergreen Hybrid	Sep 11	11,858	10,406	524.3	473.9	1.98	1.84
Golden Glory	Aug 27	9,438	10,527	695.7	635.3	2.01	1.83
Tendermost	Sep 1	9,801	7,986	574.8	504.2	1.86	1.40
Huron	Sep 4	7,569	10,043	544.5	595.0	1.91	2.15
Golden Cross Bantam	Sep 10	9,438	10,043	473.9	443.7	1.23	1.10
Gold Rush	Aug 23	10,043	10,648	847.0	816.8	2.66	2.50
Erie	Sep 1	8,833	7,260	605.0	403.3	1.89	1.39
Aristogold	Sep 4	11,011	9,680	615.1	504.2	2.42	1.92
Iowana	Aug 27	9,922	9,196	564.6	524.3	1.56	1.56
KNF 45	Sep 1	10,890	10,043	615.1	594.9	2.11	1.91
Golden Rocket	Aug 22	8,833	9,559	453.8	403.8	1.03	0.87

leaves about 2 weeks after the plants were treated, but the plants recovered and looked normal before harvest time. The rolling condition of the leaves did not result in delayed maturity of the sweet corn. All plots were harvested September 11 and approximately 90 per cent of the corn was mature on that date. Harvest records were taken in the same manner as for the variety test. The results are recorded in Table II.

TABLE II—EFFECT OF DIFFERENT FORMULATIONS OF 2,4-D ON YIELD, STAND, AND NUMBER OF MARKETABLE EARS

Treatment*	Stand (Stalks Per Acre)	Number of Marketable Ears (Dozens Per Acre)	Weight of Marketable Ears (Tons Per Acre)
Sodium salt	13,020	829.0	2.37
Triethanolamine salt	12,536	742.3	2.01
Alkanolamine salt	12,657	708.0	2.00
Isopropyl ester	12,584	804.8	2.33
Butyl ester	12,947	863.3	2.36
Check	12,899	766.5	2.14

*All treatments applied at the rate of 0.7 pounds of 2,4-D acid equivalent per acre.

There was no significant difference between treatments for stand, yield, or the number of marketable ears.

SUMMARY

In this preliminary report on the effect of 2,4-D sprays on sweet corn, the spray treatments did not significantly increase or decrease the number of marketable ears, yield, or stand for any of the varieties tested.

The maturity of those varieties of sweet corn tested did not appear to be affected by the use of 2,4-D.

There was no significant increase or decrease in the number of marketable ears, yield, or stand for the five different formulations of 2,4-D tested as compared with the check plot.

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Pre- and Post-Emergence Chemical Weeding of Several Vegetables[1]

By R. D. SWEET and J. R. HAVIS, *Cornell University, Ithaca, N. Y.*

CHEMICAL soil treatments have been advocated by several investigators (1, 2, 3, 4, 5) as a means of weeding vegetables. The questions of materials, rates, and timing, however, have not yet been answered. The purpose of these studies was to determine the relative merit of several petroleum products, two growth regulators, and a dinitro compound when applied to the soil as non-selective herbicides for weeding various vegetables.

Two types of tests were conducted, "pre-emergence" applications on direct seeded crops, and "post-setting" applications on transplanted vegetables. For the sake of clarity these two types will be presented separately.

PRE-EMERGENCE TESTS

In these tests the treatments were applied after the crops were planted but before they had emerged. Weed seeds had been allowed to germinate before planting.

Experiment No. 1:—The following materials were used: dinitro ortho secondary butyl phenol in oil (Dow Contact herbicide),[2] and five petroleum compounds[3] of widely different boiling range and aromatic content, as is indicated in Table I.

Stoddard solvent is the material used in the East for spraying carrots. Heavy aromatic naphtha is similar in boiling range to kerosene. Tar L is an aromatic distillate which when broken into two components produces HB as the lighter and Tar H as the heavier fractions. The latter contains compounds which are essentially non-volatile and which are dissipated from the soil principally by action of microorganisms.

TABLE I—PETROLEUM PRODUCTS USED IN THE PRE-EMERGENCE TESTS

Type of material	Code Symbol	Approximate Boiling Range (Degrees F)	Approximate Aromatic Content (Per Cent)
Stoddard Solvent	Var. 2	300–400	10–15
Heavy aromatic naphtha	HAN	350–550	75+
Aromatic distillate	HB	400–650	75+
Aromatic distillate	Tar L	400+	75+
Aromatic distillate	Tar H	650+	75+

On the basis of previous tests the following rates in gallons per acre were used: 25 and 50 of HAN, HB, and Tar L; 15 and 25 of Tar H; 50 and 80 of Varsol 2; 1 and 2 of the Dow Contact. All materials except Varsol 2 at 80 gallons were emulsified and brought up to 100 gallon volume. A knapsack sprayer was used for all applications.

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[1]Published as Paper No. 298 Department of Vegetable Crops, Cornell University, Ithaca, N. Y.

[2]Courtesy Dow Chemical Co.

[3]Courtesy Standard Oil Development Co.

The soil used in these tests was a Dunkirk sandy gravelly loam of good fertility with a potentially high weed population. Plots were 10 feet by 10 feet and replicated three times. On July 12 the area was given a final fitting. About 1 inch of irrigation was applied July 18. The succeeding two days several showers occurred. On July 26 one-half of each plot was sown to radish and one-half to beets by means of a hand seeder.

Treatments were applied 2 days after seeding. At this time the radish had radicles ¼ inch to ⅜ inch long, but the beets did not yet show evidence of germination. Weed seedlings, especially purslane, were very abundant at the soil surface. A few large grass plants not uprooted in the fitting process were growing vigorously.

No plots received cultivation with conventional equipment, but the check plots were hand weeded 3 weeks after planting. The weeds were so prolific in these plots that yields would have been materially reduced if they had not been weeded. Weed counts were made just prior to hand weeding. The first harvest of radishes was made 4 weeks after sowing and the final harvest 3 days later. Beets were harvested at the bunching stage on September 16, 7 weeks after sowing.

A summary of the data obtained on weed population and yield of radish and beets is presented in Table II.

TABLE II—THE EFFECT OF PRE-EMERGENCE MATERIALS ON THE WEED POPULATION AND YIELDS OF RADISH AND BEETS

Material	Rate/A Gals	Weeds/Sq Ft (3 Weeks After Treatment)	Yield (Ounces) Per 10 Feet of Row	
			Radish Roots	Beet Roots
Var. 2	50	1.1	16.4	27.8
(Stoddard solvent)	50	2.9	15.3	27.8
H.A.N	50	0.9	15.3	33.2
(Aromatic naphtha)	25	1.6	18.0	24.2
H.B	50	0.6	8.9	15.6
(Aromatic distillate)	25	1.3	9.4	36.4
Dow Contact	2	1.3	8.9	20.2
(Di-nitro)	1	1.2	14.2	22.5
Check (Handweeded)	—	10.8	14.7	28.9
Tar L	50	1.3	9.4	**
(Aromatic distillate)	25	1.3*	**	**
Tar H	25	3.1*	**	**
(Aromatic distillate)	12	4.8*	**	**
L.S.D. 5 per cent		2.4	7.5	17.3
1 per cent		3.3	10.3	23.9

*Mostly large weeds.
**Yields extremely low due to weeds.

Excellent control of weeds was obtained in all treated plots except those receiving the aromatic distillates of a tar nature. Tar L at 50 gallons per acre gave fairly good control of the seedling weeds, but not of the few large grasses which were present at time of treatment. Tar H was not satisfactory as an herbicide. It was difficult to apply except at low concentrations, and under these conditions gave poor weed

control. Havis (2) working with pure hydrocarbons, has shown that those which boil higher than 575 degrees to 600 degrees F have relatively poor herbicidal properties. This probably accounts for the unsatisfactory performance of the tars.

No yield records were taken in the tar plots, except Tar L 50 gallons, because the crops were badly stunted by excessive weed growth. Where data were obtained, there was no significant difference in yield between any of the treated plots and the hand weeded checks, as is indicated in Table II. There was, however, a significant reduction by HB 50 gallons when compared with the highest yielding treated plots. The di-nitro at the 2 gallon rate caused a similar reduction in the radish but not the beet plots.

Experiment No. 2:—It was apparent from the above experiment that crops could be successfully weeded by applying any one of several petroleum compounds or a di-nitro as a pre-emergence treatment. Variations in the time of applying these materials, however, could conceivably influence their effectiveness as herbicides and might also affect their toxicity to crops.

To test the effect of timing a subsequent experiment was conducted. The soil was fitted August 22 to destroy a crop of summer grass and purslane. Live sprigs of the latter, however, remained on top of the ground. A shower came August 25. On August 29 the area was planted to radish and spinach. Numerous purslane and other broadleaved annual weed seedlings were present. Spinach was substituted for beets because of the late sowing date. The same size of plot and number of replications was used in this test as in the preceding one.

Treatments consisted of Dow Contact at 1 and 2 gallons per acre and the aromatic distillate HB at 15 and 25 gallons per acre, applied as follows: treatment "A" immediately after planting, "B" 1 day later, and "C" 2 days after planting. About 1 inch of rain fell between the "A" and "B" treatments. Radish and spinach emerged 4 and 7 days respectively after sowing. Weed counts were made September 23, approximately 3 weeks after the last treatment. Radishes were harvested in three pullings; September 24, October 2 and 9. Spinach was harvested October 9.

The findings of this experiment are presented in Tables III, IV, and V. It can be seen in Table III that all treatments significantly reduced the number of weeds per square foot. The aromatic distillate HB at 25 gallons, however, gave significantly better weed control than did the di-nitro compound at the 1 gallon rate (Table IV). On the other hand, this rate of HB reduced the stand and the yield of both radish and spinach. The high rate of di-nitro exhibited the same tendency, but it was less pronounced.

The effect of timing is summarized in Table V. Since the weeds had already germinated before the first treatment was applied, timing had little influence on weed control. In contrast, however, the stand and yield of radish were significantly affected by the time of treating. Treatments applied immediately after planting were more toxic than those applied only 2 days prior to crop emergence. The reason for this anamolous situation is not clear. Since treatment "A" was applied

TABLE III—THE EFFECTS OF PRE-EMERGENCE SPRAYS ON WEEDS, RADISH AND SPINACH

Material	Gallons Per Acre	Time of Treat-ment	Weeds Per Sq Ft	Plants Per 10 Feet of Row		Yield (Ounces) Per 10 Feet of Row	
				Radish	Spinach	Radish Roots	Spinach Tops
H.B.	25	A	1.8	45.6	8.3	7.8	2.4
(Aromatic distillate)		B	2.8	66.1	10.6	12.1	3.4
		C	1.1	80.0	12.2	13.8	3.4
	15	A	4.6	66.7	13.6	10.5	4.7
		B	5.3	91.4	15.6	15.5	7.6
		C	3.7	80.3	18.9	15.9	8.4
Dow Contact	2	A	7.1	25.0	11.9	4.8	4.6
(Di-nitro)		B	4.0	42.0	16.1	8.3	6.8
		C	7.0	65.6	11.4	11.9	5.2
	1	A	9.9	62.5	13.9	11.1	7.6
		B	5.0	55.6	14.4	11.6	6.2
		C	12.0	74.7	18.3	15.2	9.1
Check	....	—	24.1	91.9	16.7	18.7	7.1
L.S.D.		5 per cent	8.2	34.5	8.7	6.7	3.9

TABLE IV—SUMMARY OF THE VALUE OF MATERIALS AS PRE-EMERGENCE SPRAYS

Material	Gallons Per Acre	Weeds Per Sq Ft	Plants Per 10 Feet of Row		Yield (Ounces) Per 10 Feet of Row	
			Radish	Spinach	Radish Roots	Spinach Tops
H.B.	25	1.9	63.9	10.4	11.3	3.1
(Aromatic distillate)	15	4.5	79.4	16.0	14.0	6.9
Dow Contact	2	6.0	44.9	13.2	8.3	5.5
(Di-nitro)	1	8.9	64.3	15.6	12.5	7.6
Check*	•	24.1	91.9	16.7	18.7	7.1
L.S.D. 5 per cent		4.6	25.5	5.7	4.8	2.4

*For statistical comparisons see Table III.

TABLE V—SUMMARY OF THE INFLUENCE OF TIME OF TREATMENT ON THE EFFECTIVENESS OF THE MATERIALS

Time of Treatment	Weeds Per Sq Ft	Plants Per 10 Feet of Row		Yield (Ounces) Per 10 Feet of Row	
		Radish	Spinach	Radish Roots	Spinach Tops
A At planting time	5.9	49.9	12.0	8.6	4.8
B 1 day after planting	4.3	64.3	14.2	11.9	6.0
C 2 days after planting	5.9	75.1	15.2	14.2	6.5
Check*	24.1	91.9	16.7	18.7	7.1
L.S.D. 5 per cent	N.S.	22.0	N.S.	4.2	N.S.

*For statistical comparison see Table III.

about 18 hours prior to a 1 inch rain, perhaps the toxicants were washed far enough into the soil to come into contact with the crop seed. Subsequent preliminary greenhouse tests have neither corroborated nor disproved this theory. Another possible explanation may be that the emulsions were diluted when applied on wet soils as in treatments "B" and "C". This might render the herbicides less toxic to the crop plants as they emerged. No greenhouse work has been done to check this theory.

POST-SETTING TESTS

The purpose of these tests was to investigate the possibility of weeding transplanted crops such as cabbage, broccoli, and tomatoes with chemicals to eliminate hand hoeing. Herbicides used were methyl ester of naphthalene acetic acid at 3 pounds per acre; NH_4 salt of 2,4–D[3] at 3 pounds per acre; Dow Contact at 3 gallons per acre; Varsol 2 at 100 gallons per acre; HAN at 50 gallons per acre, and aromatic distillate HB at 50 gallons per acre (see Table I). Applications were made over the entire soil surface on August 12, 3 weeks after the crops had been set in the field. A knapsack sprayer was used, and reasonable care was taken to prevent direct spray from hitting the crop plants. Weeds, which included grasses, purslane and other broadleaved species, were beyond the seeding stage. Weed counts were made September 16.

Although no direct application was made on the crop plants, 2,4–D was injurious to the three crops tested. No other material produced appreciable crop injury. The unsatisfactory weed control for 2,4–D and MENA, as shown in Table VI, was partially due to growth of grasses. Good weed control was obtained in plots treated with Dow Contact and the three petroleum products.

The quantity of material used on an acre basis could have been markedly reduced if spraying had been restricted to the area between plants. The speed of weeding a given length of row was greatly accelerated by using a knapsack sprayer instead of a hoe. This was especially true where stones were a problem.

TABLE VI—CONTROL OF WEEDS IN TRANSPLANTED CROPS BY MEANS OF NON-SELECTIVE HERBICIDAL SPRAYS

Material	Rate Per Acre	Average Number Weeds Per Square Feet
HAN	50 gal	1.8
HB	50 gal	2.7
Dow Contact	3 gal	3.0
Varsol 2	100 gal	3.8
2,4-D	3 lb	9.3
MENA	3 lb	10.7
Check	——	13.2
L.S.D. 5 per cent		5.6
1 per cent		8.4

SUMMARY

The herbicidal value of five petroleum products, two growth regulators and a di-nitro were studied. Treatments consisted of "Pre-emergence" sprays on the direct-seeded crops; radish, beets, and spinach, and "post-setting" sprays on the transplanted crops; tomatoes, cabbage, and broccoli.

When weed seeds had already germinated, excellent control was obtained with several petroleums having a boiling range below 650 degrees F, but not with heavier fractions. Di-nitro ortho secondary

[3]Courtesy Dow Chemical Co.

butyl phenol in oil also gave good control. Under these conditions, time of application had little influence on weed kill. On the other hand, timing had a pronounced effect on the toxicity of the herbicides to the crops. Application made immediately after planting were more toxic to the vegetables than were those made just prior to crop emergence. The reason for this unexpected behaviour is not clear. It may be that rains on the early treatments brought the toxicants into contact with the seed, or perhaps the wet soils present at the time of the later treatments resulted in a diluting of the emulsions.

Post-setting treatment showed the possibilities of eliminating hand hoeing of widely spaced transplanted crops by the use of contact herbicides. 2,4–D and methyl ester of naphthalene acetic acid were not satisfactory for this purpose.

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Weed Control in Certain Vegetable Crops with Soil Applications of 2,4–D[1]

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The results of earlier work (6) indicated that good control of several annual weeds could be obtained by soil applications of 2,4–D (2,4–dichlorophenoxyacetic acid) at the rate of 4 pounds or more of the acid equivalent per acre. It was suggested that lower rates might be satisfactory but information on this point was insufficient. Evidence was presented which indicated that 2,4–D does not kill dormant seeds and therefore to be effective must be present in toxic concentrations at the time the weed seeds are germinating. This is in agreement with results reported recently by Mitchell and Brown (5).

In the earlier study (6) results with sweet corn and onions suggested that 2,4–D soil treatments might be used to control weeds in these crops but due to frequent injury more research work was needed. The purpose of the experiments reported here was to study the effect of 2,4–D formulation and rate, method and time of application on weed control and crop injury in sweet corn, onions, potatoes and asparagus.

Materials and Methods

Experiments with Golden Cross Bantam sweet corn, Golden Globe onions grown from sets, and Mary Washington asparagus were conducted on Miami silt loam soil at Madison, Wisconsin, in 1947. Experiments with Brigham Yellow Globe onions grown from seed and with Chippewa potatoes were located on peat soils in Southern Wisconsin. The soils were all fertile and the pH ranged from 6.0 to 7.5 in the various fields but since there was no correlation of pH with results obtained, it is not reported for the individual fields.

A formulation of the sodium salt of 2,4–dichlorophenoxyacetic acid containing 70 per cent acid was used in all experiments except one on onions where several formulations were compared. In the latter experiment the pure acid, isopropyl ester and triethanolamine salt containing 100, 37 and 20 per cent acid equivalent were also used. The pure acid was mixed with sand and applied dry, but all other soil applications in all the experiments were made as an aqueous spray to the soil surface using 200 gallons of water per acre. The rates of application were 2, 3 and 4 pounds of 2,4–D acid equivalent per acre for all soil treatments. The direct sprays were applied as a 0.1 per cent solution at 100 gallons per acre thus giving 0.8 pounds of 2,4–D acid per acre. A knapsack sprayer equipped with a fan-type nozzle was used throughout the experiments. Where the treatment called for mixing the 2,4–D into the soil this was done with either a rotary tiller or a hand cultivator working the soil thoroughly to a depth of 3 inches. All plots receiving other treatments were worked-up in the same way at this time and planting was done immediately afterward. Soil sur-

[1]The authors are indebted to the Dow Chemical Company and the American Cyanamid Company for supplying the chemicals used in these experiments.

face applications were made either immediately after planting or 1 to 2 days before crop emergence. The soil was not disturbed until after the first weed counts were made.

Either four, five or six replications were used in all experiments. The experimental design was a Latin square in three of them and a randomized block in all others. The plot size used for onions was five rows 10 feet long with rows spaced 14 to 16 inches apart and for potatoes it was four rows 14 feet long with 3 feet between rows. For the sweet corn planted June 5 the plots consisted of two rows 36 feet long and 3½ feet apart while for that planted June 10 the plots were five rows wide and 24 feet long with 3 feet between rows. The treatments on asparagus were made in an 8-year-old bed with rows 4 feet apart using 40 feet of row for each plot. In the case of the asparagus and of the sweet corn planted June 5, 2,4–D treatments were made on 24- and 12-inch strips respectively over the rows and in harvesting 2 feet on each end were discarded. In all other experiments the entire plot was treated and in harvesting one row on each side of the plot and a border strip on each end was discarded.

Onions from seed were planted with a garden seeder, but all other crops were planted by hand spacing the seeds, seed pieces or sets uniformly. The onion sets were between ½ and ¾ inches in diameter and the potato seed pieces used weighed 1 ounce. The onion sets were spaced 3 inches apart in the row and the potato seed pieces 1 foot apart. Two kernels of sweet corn were planted every foot in the planting made June 5 and six kernels every 3 feet for the planting made June 10. Stand counts were made after complete emergence for the sweet corn and potatoes and at harvest time for the onions. No thinning was done in any experiments except in the June 5 sweet corn planting which was thinned to one plant every foot. Harvesting was done by hand at the stage of maturity that these crops are normally harvested. For the asparagus this was in May and June; for onions from sets, August 11; for sweet corn, August 27 to September 2; for onions from seed, early September and for potatoes, October 2 to 4.

The following weeds were present in considerable numbers in one or more of the experiments: pigweed *(Amaranthus retroflexus)*, lambs-quarters *(Chenopodium album)*, purslane *(Portulaca oleracea)*, annual smartweeds *(Polygonum spp.)* shepherds-purse *(Capsella Bursa-pastoris)*, witchgrass *(Panicum capillari)*, and foxtail *(Setaria spp.)*.

Accurate counts were made of the number of each kind of weeds present in all plots in all the experiments 5 to 7 weeks after planting. A second count was made 2 to 4 weeks later in the onion experiments. In the latter experiments all weeds were counted in a 4 inch-wide strip in the three harvest rows. In the other experiments the weeds enclosed by an 18 inch square frame in four locations in each plot were counted. All weeds were removed at time of counting and all plots were cultivated immediately afterward. Subsequent weedings and cultivations were given as in standard commercial practice. Thus the difference in weed growth due to treatment was largely eliminated as a factor affecting yield.

The 1947 growing season in Southern Wisconsin was characterized by a cold, wet spring followed by extremely hot and rather dry weather in August. From April until late in July soil moisture in the experimental fields varied from ample to sometimes excessive but was never low.

Results

Sweet Corn:—The results of two experiments on sweet corn are shown in Tables I and II. In the planting of June 5 (Table I), the broad-leaved weeds on the check plots were mostly pigweed and purslane and were almost completely eliminated by all 2,4–D treatments. Grasses present were mostly foxtail and the 2,4–D treatments reduced the average number by approximately 70 per cent compared with the check. In the planting of June 10 (Table II) purslane accounted for practically all of the broad-leaved weeds and witchgrass for practically all of the grasses. As shown in Fig. 1, the apparent control of both

FIG. 1. Effect of 2,4–D soil treatment on weed control in sweet corn planted June 10. *Left*—check. *Right*—two pounds of 2,4–D per acre sprayed on soil surface the day after planting.

broad-leaved and grass weeds was good. The weed counts confirm this for grasses, but show an average of only around 50 per cent reduction in the number of broad-leaved weeds. This is explained by the fact that the interval between the time the sweet corn was planted and the time the weed counts were made was 8 days longer than in the first experiment and a large number of small purslane plants were present. Apparently the 2,4–D had been dissipated before the counts were made. This rapid loss in toxicity in warm moist soil is in agreement with results reported previously (6).

In these experiments the 4-pound rate of application in general gave only slightly better weed control than the 2-pound rate and there was little difference in results for the two methods of application. The rela-

TABLE I—EFFECT OF RATE AND METHOD OF APPLICATION OF 2,4–D ON WEED CONTROL AND THE STAND, MATURITY AND YIELD OF SWEET CORN (PLANTING OF JUNE 5)

Treatment		Average Number Weeds Per Square Foot		Average No. Corn Plants Per Plot	Average No. Tassels Per Plot on Aug 5	Yield of Marketable Ears (Tons Per Acre)
Pounds 2,4-D Per Acre	Method of Application	Broadleaves	Grasses			
0	———	12.1	12.3	81	50	2.00
2	Mixed into soil*	0.4	4.8	73	37	1.75
2	Sprayed on soil surface**	0.2	2.0	76	31	1.71
4	Mixed into soil*	0.4	4.6	53	27	1.34
4	Sprayed on soil surface**	0.0	4.7	61	26	1.56
L.S.D. 5 per cent		1.3	5.8	19	11	0.26
1 per cent		1.8	8.0	27	16	0.35

*Applied immediately before planting.
**Applied immediately after planting.

TABLE II—EFFECT OF RATE AND METHOD OF APPLICATION OF 2,4–D ON WEED CONTROL AND THE STAND, MATURITY AND YIELD OF SWEET CORN (PLANTING OF JUNE 10)

Treatment		Average Number Weeds Per Square Foot		Average No. Corn Plants Per Plot	Average No. Tassels Per Plot on Aug 6	Yield of Marketable Ears (Tons Per Acre)
Pounds 2,4-D Per Acre	Method of Application	Broad-leaves	Grasses			
0	———	41.2	17.5	30	14	1.92
2	Mixed into soil*	25.8	7.3	27	15	2.33
2	Sprayed on soil surface**	24.2	5.7	35	13	2.95
4	Mixed into soil*	17.6	5.6	32	12	2.71
4	Sprayed on soil surface**	17.6	3.1	27	10	2.26
L.S.D. 5 per cent		3.2	2.9	N.S.	N.S.	0.63
1 per cent		4.3	3.9			

*Applied day before planting.
**Applied day after planting.

tively good control of grasses compared with broad-leaved weeds is supported by results of other workers (1, 3). The greater control of grasses with 2,4–D soil treatments as compared with direct sprays makes this method of application a promising one.

In the planting of June 5 it was noted that there was a delay in emergence of sweet corn on all the plots treated with 2,4–D. This delay in emergence was reflected through the season and resulted in a slight delay in maturity as shown by tassel counts made August 5 (Table I). The yield of unhusked ears was reduced by approximately 12 and 30 per cent for the 2- and 4-pound rates of application respectively. With the 4-pound application there was also a significant reduction in stand but the reduction in yield cannot be attributed to this since extra seed was planted and the corn thinned to a uniform stand after making plant counts. In previously reported results (6), 2,4–D soil treatments caused a similar delay in emergence and maturity but did not result in reduced stand or yield. Anderson and Wolf (1) have reported good control of weeds and no injury to field corn with an application of 2.7 pounds per acre.

In the planting of June 10, the stand was poor but there was no apparent difference due to treatment in rate of emergency, stand, and

maturity. This is substantiated by the data in Table II. The lower yield on the check is probably due to competition from weeds before they were removed. The first cultivation and hoeing was done July 21 which was about 10 days later than it should have been done, and corn on the check plots was getting yellow from nitrogen starvation, whereas on the plots given a soil treatment there was little or no weed competition and the corn was dark green.

The authors have no fully satisfactory explanation for the difference in the amount of injury to the sweet corn from 2,4–D in these two experiments. The experiments were located only a few miles apart and on the same soil type but the 5 days difference in planting dates in relation to precipitation may have been involved. On June 12 and 13 there was a 3.2 inch rainfall. At this time the corn in the June 5 planting was breaking ground, while that in the June 10 planting was just sprouting. One might have expected greater injury to the planting of June 10 in this case, but since the reverse was true, any explanation becomes more difficult.

Onions Grown from Sets:—A planting of onion sets was made May 5 and given the same 2,4–D soil treatments as the sweet corn. The most common weeds in the field were pigweed, purslane and foxtail. Compared with the checks the percentage reduction in number of both grasses and broad-leaved weeds was approximately 50 and 70 per cent for the 2- and 4-pound 2,4–D applications respectively. The weeds present in the plots treated with 2,4–D averaged considerably smaller than those in the check plots. Comparing the weed counts where 2,4–D was mixed into the soil immediately before planting with those where it was sprayed on the soil surface just after planting, the differences were slight but generally in favor of the surface spray. A second weed count was made 8 weeks after planting, but there was practically no difference in number of weeds between the untreated and treated plots indicating that the 2,4–D applied had been dissipated before these weeds started.

There was little or no delay in emergence of the onions where 2,4–D was sprayed on the soil surface after planting but where mixed into the soil, emergence was delayed 10 days to 2 weeks. The yield in bushels per acre of U. S. No. 1 onions by treatment was as follows: Check, 530; 2 pounds 2,4–D mixed into soil, 326; 2 pounds 2,4–D sprayed on soil surface, 454; 4 pounds 2,4–D mixed into soil, 286; and 4 pounds sprayed on soil surface, 305. The reduction in yield for all treatments is significant at the 1 per cent level. It should be noted that 4 pounds was more injurious than 2 pounds and that where the 2,4–D was mixed into the soil the yields were lower than where it was sprayed on the surface. In the first 11 days after planting, there was only .5 inches of precipitation, thus the 2,4–D sprayed on the soil surface probably did not come in contact with the onion sets on these plots for several days after planting. This seems to be a good explanation for the effect of method of application on rate of emergence and yield. The results of this experiment indicate that 2,4–D soil treatments offer little promise as a method of controlling weeds in Golden Globe onions grown from sets. Of course, on other soil types, using

was located in the same field as the one used for the formulation experiment, but the onions were planted April 25.

The results were quite similar to those reported for the sodium and amine salts in the formulation experiment except that the reduction in number of weeds as well as stand and yield of onions was generally less. Sprays applied just before onion emergence gave good weed control and did not injure the onions even at the 4 pound rate of application. Pre-planting treatments, on the other hand, gave only fair control of weeds yet caused a marked reduction in the stand of onions which became progressively more severe as the rate of application of 2,4–D increased. This reduction in stand resulted in considerably lower yields at the normal seeding rate but at the heavy seeding rate the yield was comparable with the checks. In this experiment, therefore, it was possible to compensate for the reduction in stand due to preplanting treatments with 2,4–D by sowing more seed per acre. From a practical standpoint, however, this does not seem feasible since better weed control was obtained and there was no injury to the onions when the 2,4–D was applied just before emergence. Also, the cost of the extra seed would be a factor.

The results of pre-emergence sprays on onions planted April 21 on a well-drained peat in Racine County are shown in Table IV. Only total weed counts were made. About half the weeds on the check plots were pigweed, the balance being made up of purslane, grasses and several other species. There were practically no weeds at the time of the first weeding on the plots treated with 2,4–D even at the 2-pound rate of application. There was some reduction at the time of the second weeding but the effect was wearing off. There was a slight but not significant reduction in stand of onions but no reduction in yield.

The same treatments were applied to onions planted May 14 on a poorly-drained peat at Delavan. The soil was practically saturated when the sprays were applied May 24 and there was about ¾ inch of rain a few hours afterward. The weed population was heavy and counts of three species, lambs-quarters, pigweed, and smartweed, were large enough to give comparative data. The weed counts at the time of the first weeding (Table V) show excellent control of lambs-quarters and pigweed but poor control of smartweed. The relative resistance of the latter weed to 2,4–D soil treatments has been confirmed by supplementary experiments at other locations. There was some reduction in number of weeds at the time of the second weeding but the effects were wearing off.

The soil in this field remained so wet throughout most of the season that none of the onions developed bulbs of marketable size. Therefore, no yield records were obtained, but stand counts were made in September. The data in the table show a marked reduction in stand of onions on plots treated with 2,4–D especially at the higher rates of application. This effect on stand was noticeable a week after the treatments were applied. A commercial trial in the same field indicated the injury from 2,4–D increased as the drainage became poorer. An experiment on onions planted April 29 at Montello on another poorly-drained peat also showed a reduction in stand for 2,4–D pre-emergence sprays.

In the latter experiments the onions were planted only ½ inch deep, whereas in the other experiments they were planted about 1 inch deep. The injury to the onions from pre-emergence sprays in these experiments may be due, therefore, to poor drainage, shallow planting, weather conditions after spraying, or other factors. Drainage, however, would appear to be important. If poor drainage is involved, just how it affects the results becomes a subject for speculation. Some of the factors might be more rapid movement of 2,4–D into the soil, slower dissipation of 2,4–D or lessened resistance of onions growing on wet soil.

Potatoes:—The results of a potato experiment planted May 15 on a well-drained peat at Madison are presented in Table VI. In addition to soil treatments, a direct spray of 2,4–D was applied when the potatoes were about 8 inches high. The weeds present were nearly all pigweed and were reduced in number by 2,4–D soil treatments. The 4-pound rate of application gave somewhat better control than the 2-pound rate. Although the data show a considerable number of weeds remaining, they were so severely stunted that the plots appeared nearly free of weeds. The direct spray gave better control of weeds than any of the soil treatments.

TABLE VI—Effect of Rate, Time and Method of Application of 2,4–D on Weed Control and the Yield of Potatoes

Treatment			Average No. Weeds Per Square Foot	Yield of U. S. No. 1 Potatoes (Bu Per Acre)
Pounds 2,4-D Per Acre	Method of Application	Days After Planting		
0	———	—	43.7	567
2	Mixed into soil	*	27.0	508
2	Sprayed on soil surface	1	17.3	517
2	Sprayed on soil surface	12	20.6	659
4	Mixed into soil	*	15.9	573
4	Sprayed on soil surface	1	14.8	569
4	Sprayed on soil surface	12	11.5	519
0.8	Direct spray	33	1.0	503
L.S.D. 5 per cent			10.4	N.S.
1 per cent			14.3	

*Applied immediately before planting.

There was no delay in emergence, reduction in stand, or decrease in yield for any of the soil treatments as compared with the check. The direct spray severely stunted the potatoes for a period of approximately 2 weeks but later in the season plots treated in this way could not be distinguished from any others. The yield was slightly lower than the check but the difference is not significant at the 5 per cent level. This apparent resistance of potatoes to a direct application of 2,4–D was reported by Ennis (2) and should warrant further study. The external and internal appearance of the potatoes was not affected by either the direct spray or the soil treatments.

Discussion

In these experiments, conducted under moist soil conditions, 2,4–D soil treatments gave generally good control of weeds early in the sea-

son. The toxicity disappeared rapidly as indicated by the fact that there was little or no reduction, due to 2,4–D, in the number of weeds present at the second weeding. Results in the dry season of 1946 (6) showed generally slower loss in toxicity. The decrease in rate of dissipation of 2,4–D in the soil as the moisture content decreases was discussed at some length in the latter paper.

In some of the experiments the number of weeds present decreased as the rate of application of 2,4–D increased from 2 to 4 pounds per acre. In others there was little or no difference, and in none of the experiments was the decrease in weed numbers in proportion to the increase in rate of application of 2,4–D. Wherever crop injury occurred, on the other hand, it increased almost directly with the rate of application. On the more sensitive crops, these results suggest the use of the lowest quantity of 2,4–D that will give reasonably good weed control.

In the two experiments with onions grown from seed where a comparison was made of treatments worked into the soil before planting with sprays applied to the soil surface just before emergence, the latter method gave no injury to the onions and good weed control, whereas the former caused large reductions in stand and yield of onions yet did not control the weeds as well. In the experiments with sweet corn and onions grown from sets, working the 2,4–D into the soil just before planting was compared with applying it to the soil surface just after planting. There were only slight differences in weed control but those that did occur were in favor of the soil surface sprays. On sweet corn there was little difference as regards crop injury, but on onions grown from sets, the surface sprays caused definitely less injury. In the experiment with potatoes, all three methods of application were compared; that is, worked into the soil before planting, sprayed on the soil surface just after planting, and sprayed on the soil surface just before crop emergence. There was no injury to the crop with any of the treatments, and weed control was similar for all methods of application except slightly poorer where the 2,4–D was worked into the soil before planting.

These results indicate, in general, a preference for applying 2,4–D to the soil surface after planting as compared with working it into the soil just before planting. As to whether the surface application should be made just after planting the crop or delayed until a day or two before emergence needs to be investigated further.

Although weed control with similar 2,4–D soil treatments varied somewhat between experiments, it averaged about the same on peat soil as on mineral soil (a silt loam). Weather conditions, weed species, and soil moisture appeared to affect the results more than did soil type. Good control of weeds on peat soil with 2,4–D soil treatments was also reported by the authors in an earlier paper (6). On the other hand, Krone and Hamner (4) reported poorer results on peat than on mineral soil but this might have been due to differences in rainfall, soil moisture, or the relative proportion of resistant weed species such as smartweed on the peat soil as compared with the mineral soils used.

It is apparent that results with 2,4–D soil treatments will be de-

pendent on many factors. Such things as the crop and variety planted, weed species, weather, and soil conditions may greatly influence the outcome of the experiments. Therefore, one should be cautious in drawing conclusions and especially in making recommendations until the influence of these factors is more fully understood.

Summary

The sodium salt of 2,4–dichlorophenoxyacetic acid applied to both silt loam and peat soils at the rates of 2, 3 and 4 pounds of the acid equivalent per acre gave generally good control of pigweed, lambsquarters, purslane, shepherds-purse, witchgrass and foxtail for a period of 4 to 6 weeks, but annual smartweeds were only slightly affected.

An increase in the rate of application from 2 to 4 pounds gave improvement in weed control in some experiments, but not in proportion to the increase in amount of 2,4–D applied. Whenever crop injury occurred, it increased almost directly with the rate of application.

Weed control was as good or better, and crop injury the same or less where 2,4–D was sprayed on the soil surface after planting than where it was mixed into the soil just before planting.

In an experiment comparing 2,4–D formulations, the sodium and triethanolamine salts gave similar results as regards weed control and injury to the crop (onions), whereas the isopropyl ester gave slightly better weed control but caused severe injury to the crop.

Sweet corn at one location was delayed in emergence and maturity and the stand and yield were reduced, but at another location there was no injury from 2,4–D applied to the soil either just before or just after planting.

Good results were obtained on onions grown from seed on well-drained peat soils by spraying 2,4–D on the soil surface 1 or 2 days before the onions emerged. On poorly-drained peats, the onions were severely injured by the same treatments. When 2,4–D was mixed into the soil just before planting, the stand and yield were greatly reduced.

In single experiments with asparagus and potatoes, 2,4–D soil treatments appeared especially promising, but on onions grown from sets the results were discouraging due to reductions in yield.

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Pre-Emergence and Post-Emergence Weed Control in Vegetable Crops with 2,4–D, and Oil

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ONE of the most promising of the new "hormone" weed killers is 2,4–dichlorophenoxyacetic acid. Unfortunately this chemical has shown little promise for controlling weeds in vegetable crops, because of the susceptibility of most crops to the material. However, some investigators have used the material with some degree of success under certain conditions. Barrons and Grigsby (2) used a solution of 0.75 pounds of 2,4–D acid per 100 gallons of water as a spot treatment for controlling Canada thistle in canning peas, and Ennis, Swanson, Allard and Boyd (5) used 2,4–D with some success on potatoes. Willard (11) stated in early 1947 that 2,4–D might possibly be used on sweet corn and some other such highly resistant crops.

The use of oils for killing weeds in some vegetable crops is becoming a widely established practice. Considerable basic research on the properties of oils has been accomplished in California by Crafts and Reiber (4) and others. Warren and Hanning (10) state that carrots sprayed with oil meeting the specifications of Stoddard Solvent were free from objectionable flavors at canning maturity, while those sprayed with some other oils were not free of objectionable flavors.

Lachman (7) concludes that most small annual weeds are killed with oil with the exception of ragweed. Sweet's work (9) is in agreement and he further points out that perennials, such as quack grass, bindweed, and dandelion are not easily killed with oil.

Several workers agree that carrots and parsnips (and some other Umbelliferae) can be safely sprayed with 80 to 100 gallons of oil per acre, undiluted, anytime between the 1–4 true leaf stage. Other investigators (1, 3, 6, 8) have used oil successfully as a pre-emergence treatment on some slow-germinating crops.

MATERIALS AND METHODS

The butyl ester of 2,4–D was supplied by the Sherwin Williams Company, and the Stoddard Solvent was supplied by the Standard Oil Company of Ohio. The work was accomplished on the vegetable farm of The Ohio State University. The soil was Miami silt loam.

In some instances the 2,4–D spray mixture was applied at the rate of 160 gallons per acre, using a 3-gallon compressed air sprayer, and in other instances a "concentrate" sprayer was used and the rate was 25 gallons per acre. The amount of water used did not appear to alter the herbicidal effectiveness of the material. The following concentrations of the butyl ester of 2,4–D were used per acre: 0.13 pounds, 0.33 pounds, 0.66 pounds, 1.32 pounds, 1.98 pounds, and 2.6 pounds. The Stoddard Solvent was applied with a 3-gallon compressed air sprayer in all instances. Oil was used as a "strip" treatment ((row only) and as 50- and 100-gallon per acre treatments overall.

The following weed species were present in appreciable numbers:

Rough pigweed *(Amaranthus retroflexus)*, purslane *(Portulaca oleracea)*, foxtail *(Chaetochloa viridis)*, and crabgrass *(Syntherisma sanguinale)*. Canada thistle *(Cirsium arvense)* was also present in the asparagus planting.

Experimental Results

2,4–D Pre-Emergence with Twenty-Five Vegetable Crops:—Concentrations of 0.13, 0.33, 0.66 and 1.32 pounds of the butyl ester of 2,4–D per acre were used as pre-emergence herbicidal treatments with field plantings of 25 vegetable crops. The three lower concentrations were applied immediately after planting on July 21, while the concentration of 1.32 pounds butyl ester was applied approximately 24 hours later.

The concentrations of 0.13 and 0.33 pounds of the butyl ester per acre did not materially reduce the weed problem, while the concentration of 0.66 pounds per acre gave adequate control of all weeds for a period of 3 weeks and the concentration of 1.32 pounds per acre gave excellent weed control for 6 weeks.

Of the 25 vegetable crops, five emerged and grew satisfactorily throughout the 8-week period of observation, in the area treated with 1.32 pounds butyl ester per acre. These five crops were sweet corn, snap beans (Fig. 1), mung bean, asparagus, and potato. In addition to

Fig. 1. Pre-emergence treatment of sweet corn, lima bean and snap bean with 1.3 pounds of the butyl ester of 2,4–D per acre; foreground treated, background untreated. Picture taken 6 weeks after treatment.

these five crops, four additional crops grew satisfactorily in the area sprayed with 0.66 pounds butyl ester per acre. These four crops included tomato, pea, lima bean, and cucumber. All other crops were seriously injured or completely eliminated by these concentrations. These crops included chinese cabbage, head lettuce, brussels sprouts, kale, onion, carrot, parsley, parsnip, radish, turnip, leaf lettuce, cauliflower, broccoli, beet, endive and spinach.

2,4–D Post-Emergence with Mung Bean and Potato:—Concentrations of 0.33, 0.66, 1.32, and 1.98 pounds of the butyl ester of 2,4–D per acre were applied to a field planting of mung beans. Planting was accomplished on June 5, and some emergence of beans was noted on June 10. One week after emergence, four plots were sprayed with the above concentrations, respectively. Three weeks after emergence four additional plots were sprayed, and 5 weeks after emergence four remaining plots were sprayed.

All concentrations and all times of application caused a severe initial twisting of bean plants, and the rate of recovery was in proportion to the concentration used. The lower concentrations of 0.33 and 0.66 pounds butyl ester per acre did not materially reduce the total weed population as the most important weeds were foxtail and crabgrass. The concentration of 1.32 pounds butyl ester per acre applied 1 week after emergence caused some injury to the bean plants, but also materially reduced the population of all weed species present. Later treatments with this concentration were not as successful. The concentration of 1.98 pounds butyl ester eliminated all weed species, but caused severe damage to the beans.

Concentrations of 0.13 and 0.33 pounds of the butyl ester of 2,4–D were applied to a field planting of Katahdin potatoes at 3-weekly intervals starting as the crop was emerging on July 1. Many weeds were also emerging at the time of the first treatment. On July 14, after two treatments (July 1 and 7) the weeds were counted in five, 1-square-foot sections under each treatment and the results are presented in Table I.

TABLE I—Total Number and Species of Weeds Present in Five Square Feet of Soil Sprayed With Two Concentrations of 2,4–D

Treatment Per Acre and Times	Total Weeds Present (July 14)						
	Purslane	Pigweed	Velvet Leaf	Lady's Thumb	Crabgrass	Foxtail	Total
0.13 pounds butyl ester July 1 and 7	8	10	0	1	77	16	112
0.33 pounds butyl ester July 1 and 7	0	0	0	2	29	4	35
Untreated	247	22	8	6	96	18	397

Although the seemingly low concentrations of 2,4–D did materially reduce the weed population, considerable damage was apparent on the potato plants as a result of the repeated treatments. Potato plants in the treated areas were marked by smaller leaves, thicker and more leathery leaves, leaf midribs ⅛ inch wide on some plants, smaller plants, and stems twisted and lying flat on the ground in some instances. Until more experimental evidence is available, the use of

repeated 2,4–D treatments on Katahdin potatoes could not be recommended in Ohio.

2,4–D as a Herbicide on Asparagus:—Concentrations of 1.32, 1.98, and 2.6 pounds of the butyl ester of 2,4–D were applied to an established planting of asparagus immediately following the first commercial cutting on May 20. At the time of application the plots were seriously infested with Canada thistle, which was in the rosette stage for the most part. Other weeds present included pigweed, crabgrass and foxtail. All concentrations controlled the Canada thistle and pigweed throughout the cutting season, a period of 5 weeks, and greatly reduced the stand and size of the grassy weeds. The concentration of 2.6 pounds butyl ester was highly successful in controlling the grasses and the two lower concentrations were also effective, but to a lesser degree.

The same concentrations were applied to adjoining plots after the fourth cutting as asparagus. The weed species present were comparable to the earlier treatment but the weeds were somewhat larger at this time, and the time required for killing the weeds was somewhat longer. The stand of the grasses was not as noticeably reduced.

Both of the above treatments caused distortion of all asparagus spears that were above ground at the time of treatment, and approximately 50 per cent of the first cutting following treatment was unsatisfactory for sale. However, no damage was noted on subsequent cuttings.

At the end of the cutting season, one plot which was not previously treated, was disked. One week after disking, the butyl ester of 2,4–D was applied at the rate of 1.32 pounds per acre. The area was then sprayed with Stoddard Solvent at the rate of 50 gallons per acre. Very few weeds were present at the time of these treatments, and no Canada thistle plants were above the ground. A special effort was made to avoid contacting the tips of the asparagus spears with the materials. This treatment controlled all weeds for a period of 6 weeks except Canada thistle, and a minimum of damage was noted on the asparagus.

2,4–D Residual Effect on a Miami Silt Loam Soil:—On June 5, a plot of soil 50 by 180 feet was prepared for planting. Immediately following preparation, the plot was divided into three 60-foot sections. The first section was sprayed with 1.32 pounds of the butyl ester of 2,4–D. The second section was left untreated and the third section was sprayed with 2.6 pounds of the butyl ester of 2,4–D per acre. The spraying was done in both cases with the concentrate sprayer, using approximately 25 gallons of water per acre. After soil treatment, 12 rows were marked the entire length of the plot (180 feet), and the first four rows were planted to beets, sweet corn, snap beans, and tomato plants. The beet, sweet corn, and snap bean seed were planted with a Planet Jr. single-row seeder, and the tomato plants were planted by hand.

Two weeks later, on June 19, four adjoining rows were planted, and 2 weeks later, on July 3, the four remaining rows were planted. Considerable difference was noted between the various crops. All three plantings of beets were severely damaged by both concentrations of 2,4–D. The germination of the first planting of corn in the area sprayed

with 1.32 pounds butyl ester per acre was slightly retarded and reduced; subsequent plantings were free from damage. The germination of the first and second plantings of corn in the area sprayed with 2.6 pounds butyl ester per acre was moderately retarded and reduced with no damage on the third planting. The effects noted on the beans was similar to those noted on the sweet corn above. In addition, some leaf symptoms characteristic of 2,4–D injury were noted on the first two plantings of beans.

With the tomato plants, no injury was noted on any plants growing in the area treated with 1.32 pounds butyl ester per acre, except slight leaf symptoms on all three plantings. However, in the area treated with 2.6 pounds per acre, 85 per cent of the first planting was killed. No injury was noted on subsequent plantings, except slight leaf symptoms as noted above.

Both treatments were very effective in controlling practically all weeds for a period of 6 weeks. Some weeds were present in the rows, because in marking the soil (following treatment with 2,4–D) weed seeds were brought to the surface and germinated. The total number of weeds present in 5 square feet (five random counts of 1 square foot each) of soil under all treatments are shown in Table II.

TABLE II—TOTAL NUMBER OF WEEDS PRESENT IN FIVE SQUARE FEET OF SOIL TREATED WITH TWO CONCENTRATIONS OF THE BUTYL ESTER OF 2,4–D

Soil Treatment Per Acre (June 5)	Total Number of Weeds Present in 5 Square Foot Area	
	June 30	July 14
Untreated	339	354
1.32 pounds butyl ester	17	57
2.60 pounds butyl ester	6	11

Oil — Pre-Emerence with 26 Vegetable Crops:—In June, during a period favorable for rapid weed germination, oil at the rate of 100 gallons per acre was evenly applied to field plantings of carrot, asparagus, parsnip, dill, and radish approximately 2 days before expected crop emergence. No injury was noted on any crops, except a severe burning of a few radish seedlings that had emerged before treatment. All weeds above ground at the time of treatment were killed, and the area remained weed-free for a 2-week period. Crops in the treated area grew far more vigorously throughout the balance of the season than did the same crops in the untreated area.

In late July and early August, during a period not so favorable for rapid weed germination, the experiment was duplicated using 25 vegetable crops. Again, no injury was noted on any crops. However, the treatment did not materially reduce the stand of weeds growing in the fast-germinating crops, and was effective only if applied at least 7 days after planting, on slow-germinating crops such as parsnip, parsley, potato and spinach.

Oil — Post-Emergence with Carrot, Parsnip and Dill:—Oil was applied at the rate of 50 gallons per acre on field plantings of carrot, parsnip, and dill. One series of plots was sprayed in the 3-4 leaf stage;

a second series was sprayed in the 4-6 leaf stage; and a third series was sprayed approximately 2 weeks after the 4-6 leaf stage.

No crop injury was noted from any treatment. At the time of the first series (3-4 leaf stage) most weeds were 4 to 8 inches tall, and the comparatively low gallonage (50 gallons per acre) was ineffective in controlling the weeds present. Some small weeds were killed, but the balance were merely checked in growth for a few days. The later oil treatments were even less effective.

One section of the first series was re-treated four additional times over a 3-week period. The third treatment finished killing all weeds present. Injury was not noted on any crops until after the fifth treatment, which caused some yellowing of parsnip leaves. Following the fifth treatment, an objectionable flavor was also present in carrots harvested at this time.

SUMMARY

Pre-emergence and/or post-emergence herbicidal applications of Stoddard Solvent, and the butyl ester of 2,4-dichlorophenoxyacetic acid were used with field plantings of 26 vegetable crops.

In general concentrations of less than 0.66 pounds of the butyl ester of 2,4-D did not control the weeds encountered for any appreciable length of time, while higher concentrations of 1.32, 1.98, and 2.6 pounds eliminated or controlled all weeds for at least 6 weeks.

Of 25 vegetable crops, only five grew satisfactorily when 1.32 pounds of the butyl ester of 2,4-D was applied as a pre-emergence treatment. These five included sweet corn, snap bean, mung bean, potato and asparagus. In addition to the above five crops, four additional crops — tomato, pea, cucumber, lima bean — grew satisfactorily in the area sprayed with 0.66 pounds butyl ester per acre. The remaining 16 crops did not tolerate concentrations (pre-emergence) necessary to effect practical weed control.

As a post-emergence treatment, 1.32 pounds of the butyl ester per acre, applied to mung beans 1 week after emergence gave adequate control of all weeds encountered for a period of 6 weeks.

Repeated treatments of 0.13 and 0.33 pounds of the butyl ester of 2,4-D reduced the number and size of weeds growing in a plot of Katahdin potatoes, but serious injury was caused to the crop.

Concentrations of 1.32, 1.98, and 2.6 pounds of the butyl ester of 2,4-D per acre controlled all weeds in a field of asparagus throughout the cutting season, when applied immediately following the first cutting of asparagus. A minimum of injury was noted on the asparagus.

A ground application of 1.32 pounds of the butyl ester of 2,4-D per acre caused serious injury to beets planted 4 weeks later, but only slight injury to sweet corn, snap beans, and tomatoes planted immediately after treatment. A ground application of 2.6 pounds per acre also caused severe injury to beets planted 4 weeks later, and severe injury to sweet corn, snap beans, and tomato plants planted immediately after application, with little injury on later plantings of these three crops.

One hundred gallons of oil as a pre-emergence treatment was effec-

tive in controlling weeds in carrot, asparagus, parsnip, radish and dill when applied in June during a period favorable for rapid weed germination. During a later perioid (not favorable for rapid weed germination) oil was effective as a pre-emergence herbicidal treatment only on such slow germinating crops as parsley, parsnip, asparagus and potato.

As a post-emergence treatment, 50 gallons of oil, applied at several stages of crop growth, caused no injury on carrot, parsnip or dill, but did not control weeds more than 2 inches tall.

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Pre-Planting Soil Treatments with 2,4–D for Weed Control in Spinach

By L. L. Danielson, *Virginia Truck Experiment Station, Norfolk, Va.*

Results of preliminary soil treatment tests with 2,4–D in 1946 (1) showed that certain summer growing broadleaf and grass weeds could be controlled in this way. This suggested the possibility of using 2,4–D as a pre-planting soil treatment for control of weeds in the spinach crop. An experiment was arranged in the fall of that year to canvass the possibilities of such a method for the over-wintered spinach crop.

Experimental Procedure

The preliminary soil treatment trials showed that 1.4 pounds of the sodium salt of 2,4–D per acre gave very satisfactory weed control. As a result, a standard rate of 1.4 pounds of this material was used on all plots in the spinach trials using water rates of 100, 200, 300, 400, and 500 gallons per acre to make the application on the various plots. In the preliminary trials the various rates of 2,4–D in 500 gallons of water were applied per acre to insure a uniform distribution of the chemical. Since this amount of water per acre would be a problem in any practical application on a commercial acreage, the experiment described here included the study of water rate.

The spray applications were made on the spinach beds after they had been prepared as for planting. Plot size was 50 feet of bed 4½ feet wide, using four replications of each treatment. The soil type involved was a Sassafras sandy loam having a pH of 6.2.

Plantings of spinach were made in the various treatments at 4- and 12-day intervals after application of the chemical to determine the time interval required between spraying and planting. Due to packing of the soil it was necessary to use a Meeker harrow to loosen the soil in the beds for the 12-day planting. This piece of equipment loosens the soil without turning up new weed seeds. The record of rainfall during the period of treatment and planting is given in Table I.

TABLE I—Rainfall at Time of Treatment and Planting

Date	Treatment	Rainfall (Inches)
Oct 28	Treatment Date	——
Nov 1	4-Day Planting Date	——
Nov 3	————	1.46
Nov 4	————	0.05
Nov 8	————	0.31
Nov 10	12-Day Planting Date	——

The soil was moist at the time of treatment on October 28th. The 4-day planting was made on November 1, and the 12-day planting was made on November 10. The wilt resistant Virginia Savoy variety of spinach was used. Plots were fertilized in the usual way and were harvested on April 18, 1947.

Results

Weed control was maintained satisfactorily in all treated plots so that hand labor was not required for this purpose.

The 4-day plantings in the treated plots produced poor stands of low vigor. The 12-day plantings produced normal stands in the treated plots but were somewhat retarded in growth as shown by comparison with the control plots. The plants which survived the initial injury in both plantings matured normally. The 4-day plantings showed reduced yields in the treated plots. The yields in the 12-day plantings were not reduced by treatment. The results are summarized in Table II. Reduced plant weights are due to crowding resulting from the high seeding rate.

TABLE II—Stand Counts and Yields in Various Treatments*

Treatment		4-Day Planting		12-Day Planting	
Water Gals/Acre	2,4-D Sodium Salt Pounds/Acre	Stand Per Plot	Wt/Plant (Grams)	Stand Per Plot	Wt/Plant (Grams)
0	.0	659	321.3	621	267.8
100	1.4	148	565.5	607	275.7
200	1.4	83	730.9	525	297.6
300	1.4	47	741.2	599	285.3
400	1.4	76	697.4	551	293.9
500	1.4	61	721.7	581	260.4
Difference required for significance (5 per cent level)		46	122.3	Not sig.	Not sig.

*Plot Size:—50 feet of bed 4½ feet wide using 2 rows of spinach per bed. Stands and weights taken at harvest time.

Discussion

The principal weeds controlled by the treatments were chickweed (*Stellaria media*) and henbit (*Lamium amplexicaule*). These weeds are the two winter growing weeds which give trouble in the spinach crop in this territory.

Weed control was as satisfactorily maintained with 1.4 pounds of the sodium salt of 2,4–D applied in 100 gallons of water per acre, as in any of the other water rates. This indicates that a satisfactory distribution of the chemical was obtained in the low water rate and that effectiveness was not reduced. Soil moisture at the time of treatment appears to be a very important factor from the standpoint of weed kill obtained. Later experiments not reported here have shown very poor weed control when 1.4 pounds of the sodium salt of 2,4–D was applied in 100 gallons of water per acre on dry soil. This may be due to lack of penetration of the chemical into the soil solution. Another factor which may reduce effectiveness is surface particle size of dry soils, since well packed, fine soil has a greater tendency to bring moisture to the surface layer and make the chemical more generally effective during extended dry periods. The soil moisture factor will no doubt seriously limit the use of 2,4–D for pre-planting soil treatments on non-irrigated farms. Truck farms equipped with overhead irrigation can control pre-treatment soil moisture to insure a good kill and with later irrigations insure dissipation of the chemical before planting the crop.

The importance of soil moisture in the dissipation of 2,4–D in the soil has been indicated by a number of workers in this field (2, 3, 4). In the present experiment the soil was moist at the time of treatment, had a comparatively fine particle size on the surface, and was well packed. No rain fell between treatment and the 4-day planting, and as stand counts show the chemical was still present in sufficient amount to damage the spinach. A total of 1.82 inches of rain fell between treatment and the 12-day planting where normal stands were produced though early growth was retarded. These results show that plantings of spinach made in less than 12 days after treatment are not advisable even under optimum moisture conditions and that perhaps a period of 2 to 3 weeks should be allowed for the 2,4–D rate of application used here. Changing the rate of application would no doubt necessitate adjusting the interval between treatment and planting as it has been indicated previously (5) that the time interval required for dissipation of the chemical is roughly proportional to the rate of application in some soil types.

Summary

The sodium salt of 2,4–D was applied at the rate of 1.4 pounds per acre in amounts of water ranging from 100 to 500 gallons as preplanting soil treatment for spinach. Satisfactory weed control was maintained in all of the treated plots throughout the growth of an over-wintered crop of spinach.

Poor stands of spinach resulted in a planting made 4 days after treatment, whereas, normal stands were produced in a 12 day planting. Corresponding yield results were obtained.

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Weeding Sweet Corn with 2,4–D: Effects of Timing, Rates and Varieties[1]

By C. H. Dearborn, *New York State Agricultural Experiment Station, Geneva, N. Y.*, R. D. Sweet and J. R. Havis, *Cornell University, Ithaca, N. Y.*

The weeding of sweet corn with 2,4–D sprays reported by Shafer *et al* (2) indicates that the crop has a greater tolerance to 2,4–D than do many of the weeds common to corn fields. It also appears that the crop responds differently to 2,4–D at different stages in its development. The results reported by Anderson and Ahlgren (1) of studies with field corn further suggest that varieties may differ in their tolerance of 2,4–D.

In view of these reports, experiments were conducted to determine the effects of three concentrations of 2,4–D on the growth of sweet corn when applied at different stages of growth of the crop and to determine if varieties of sweet corn differ in their response to 2,4–D.

Response of Sweet Corn to Time and Rate of Application of 2,4–D

These tests were conducted at Geneva, on an area of Ontario silt loam soil 111 feet by 256 feet which was drilled with Golden Cross Bantam sweet corn at the rate of 14 pounds to the acre on June 26, 1947. This area was divided into 12 blocks 39 feet by 64 feet. Each block constituted an experiment of 12 plots 12 feet by 16 feet each. Each plot contained three record rows 3 feet apart, with a guard row on either side of each plot.

Four treatments were replicated three times on each of the 12 blocks. The treatments for 11 of the blocks were as follows: 0.0, 0.4, 0.6, and 0.8 of a pound of 2,4–D acid to the acre. The treatments for the other block were as follows: 0.0, 2.0, 3.0, and 4.0 pounds of 2,4–D acid to the acre. The triethanolamine salt of 2,4–D was used as a spray over the crop and weeds. A boom of three fan nozzles, operating at 75 to 80 pounds pressure was used to deliver the 2,4–D.

On July 1, Block 1 received the fraction of a pound series of treatments and Block 2 received the heavy 2,4–D treatments of 2.0, 3.0, and 4.0 pounds to the acre of 2,4–D acid equivalent. Approximately 30 per cent of the corn stand was showing above ground at this time. The remaining 10 blocks received the fraction of a pound of 2,4–D series of treatments as follows: July 3, Block 3; July 8, Block 4; July 14, Block 5; July 21, Block 6; July 29, Blocks 7 and 8; August 1, Block 9; August 6, Block 10; August 14, Block 11, and August 20, Block 12.

Brace roots were beginning to develop on July 29. It seemed desirable to have a test of exposed versus covered roots in case lodging became serious later in the growth of the plants. Therefore, Block 8 was treated before cultivation, and Block 9 was treated after cultivation. Broadleaved weeds were pulled during the first week in August

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in the check plots of all blocks. Records were made on the growth and yield of corn and on the weed population. The method of analysis of variance was employed in the interpretation of the data. Each block was analyzed as an experiment. All data are expressed in tons to the acre of ears of corn in the husk. Mature grain from treated and untreated plots has been planted in the greenhouse to determine if any symptoms of 2,4–D injury appear on the new plants. Corn at the canning stage from treated and check plots is being preserved for flavor studies.

Results

The yield data are presented in Table I. It will be observed that the productivity of the 12 experiments varied markedly. Although the effect of location and time cannot be separated due to the design of the experiment, it is believed that the variable productivity by dates is largely due to location. Experiments 3, 4, 7, 10, and 12 fell on very poorly drained areas, whereas Experiments 8, 9, and 11 had decidedly superior locations.

Experiments 5 and 6 were the only ones in which yield differences between treatments were statistically significant. The 0.4 and 0.6 pound treatments applied on July 14 resulted in an increase over the check plots of approximately one ton to the acre of corn. All 2,4–D treatments applied July 21 resulted in a similar tonnage per acre increase of ears-in-the-husk over their respective checks. Corn plants receiving 2,4–D treatments on this date showed a marked rolling of the blades at the W3 or late-whorl stage (3). This condition persisted nearly through the T2 or mid-green tassel stage at which time the tassel forced its way through the whorl. The rolling was most severe on the 0.8 pound treatment and persisted on some of the blades throughout the life of the plants. The only condition known to be peculiar to this date of application was that it was preceded by cloudy, showery weather for 4 days and followed by cloudy weather for 3 days with a .15 inch shower on July 22. Corn seedlings in Experiment 2 showed a similar rolling of the blades but they outgrew the deformity in 4 to 5 weeks.

TABLE I—Yield of Sweet Corn Ears in Tons to the Acre

Experiment Date (Lbs/Acre) 2,4-D	I Jul 1	II Jul 1	III Jul 3	IV Jul 8	V Jul 14	VI Jul 21	VII Jul 29	VIII Jul 29	IX Aug 1	X Aug 6	XI Aug 14	XII Aug 20
0.0	3.17	3.97*	1.57	0.68	2.16	2.33	2.13	4.75	4.25	1.19	4.43	2.36
0.4	3.46	2.96*	1.60	1.37	3.18	3.36	2.43	4.95	4.52	0.79	3.17	1.53
0.6	2.90	3.18*	1.87	1.32	3.07	3.39	1.61	3.61	4.91	0.73	3.46	1.09
0.8	2.86	2.52*	2.41	1.04	2.82	3.47	1.65	5.44	4.26	0.56	4.07	1.92
L.S.D. 5 per cent	N.S.	N.S.	N.S.	N.S.	0.56	0.63	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

*Yields for 0.0, 2.0, 3.0, and 4.0 pounds 2,4-D acid treatments.

Some lodging occurred throughout the field but the records indicated that it was not associated with treatment. Similarly there were no significant differences in number of plants lodged in connection with the before cultivation treatment of Block 8 versus application after cultivation in Block 9.

The initial kill of broadleaved weeds was practically the same for each of the light rates of 2,4–D. Commercial control was affected with all applications against the following susceptible weeds: Lamb's quarter *(Chenopodium album)*; Ragweed *(Ambrosia elatior)*; Red root *(Amaranthus riboflexus* L.). Wild Lettuce *(Lactuca canidensis* L.) was slow in responding to these light rates and was not generally killed. Alfalfa that was not completely turned under in plowing was damaged but not killed by these treatments. A few broadleaved weeds occurred as a secondary infestation in Experiment 1 about 6 weeks after the plots were treated. It should be emphasized that there was an abundance of yellow foxtail *(Setaria glauca)* a scattered stand of Smartweed *(Polygonum hydropiper)*, Barnyard grass *(Echenochloa* sp), and Quack grass *(Agrophyron ripens)*. With the exception of quack grass this later infestation of weeds appeared to be somewhat delayed in come-up as a result of the weedicide applied. The only weeds that withstood the heavy 2,4–D treatment in Block 2 were Foxtail, Smartweed, Quack grass and Wild lettuce.

Tolerance of Sweet Corn Varieties to 2,4–D

Tests were conducted on Dunkirk sandy gravelly loam of good fertility to determine the tolerance of eight important sweet corn varieties to 2,4–D (see Table II). Two replications of each variety was planted on August 12 in plots consisting of six rows 30 inches apart and 15 feet long. The surface of the soil was dry at planting time. On August 13 a light shower came. The next day 4 pounds per acre of ammonium salt of 2,4–D was applied as a spray to three of the rows in each plot. On August 15 3¼ inches of rain fell in 40 minutes.

TABLE II—Varietal Response of Sweet Corn to a Foliage Spray of 1 Pound to the Acre of 2,4–D*

Variety	Percentage of Treated Plants Malformed	Height (Inches)		
		Check	Treated	Difference
Spancross	35.8	18.0	17.5	−0.5
Seneca Dawn	65.0	19.0	19.5	+0.5
North Star	65.2	23.5	22.5	−1.0
Marcross	15.0	20.5	21.0	+0.5
Carmelcross	43.2	20.0	19.0	−1.0
Lincoln	0.0	21.0	19.0	−2.0
Golden Cross	24.8	21.0	19.5	−1.5
Ioana	0.0	20.5	20.5	0.0
Least significant difference 5 per cent	22.8			N.S.

*Observations made 3 weeks after treatment.

On August 19 corn in the untreated rows of each variety had emerged, but none was above ground in the treated plots. Two weeks after planting, data were obtained on the number of hills showing and the height of the plants. All treated plots were seriously damaged both as to actual emergence and plant height. This may have been due to the heavy rate of 2,4–D or to the cloudburst which came immediately after treating.

To gain some knowledge of varietal response to 2,4–D, when applied to the foliage, the check plots of each variety were split in half cross-

wise to the row direction. On August 26, one-half was sprayed with Ammonium salt of 2,4–D at 1 pound per acre and the remaining half left untreated. The spray was directed so that it would cover both the weeds and the corn. Purslane and red-root seedlings were very prevalent.

On September 15, 3 weeks after spraying the plants, data were taken on the height and the number of plants showing typical 2,4–D malformation. These results are presented in Table II.

As can be seen in Table II, the Seneca Dawn and North Star varieties had more malformed plants than the others. Carmelcross and Spancross were less susceptible. Golden Cross and Marcross were only slightly injured and Lincoln and Ioana showed no malformed plants. It should be pointed out, however, that the malformations even on the most susceptible varieties were not severe. Height measurements showed no significant difference between treated and untreated plants. The malformations gradually disappeared as the season progressed, but no yields were obtained because the planting was destroyed by frost. Excellent weed control was obtained in all treated plots.

Greenhouse tests were conducted to determine if rainfall could influence the toxicity of 2,4–D when applied as a pre-emergence treatment on sweet corn. On October 13, 12 flats were sown to Golden Cross and 12 to North Star sweet corn, and watered. The following day four flats of each variety were dusted with Ammonium salt of 2,4–D plus talc for a diluent at the rate of 2 pounds per acre, and four more at 4 pounds per acre. Immediately after treating one-half of the flats received a heavy watering, and were again watered heavily 2 days later. The other flats were sub-irrigated once to maintain a desirable moisture content without danger of washing the 2,4–D into the soil. On October 17, 4 days after planting corn, seedlings were visible in all flats. Two weeks after planting, data were taken on percentage emergence, and amount of malformation. The results are given in Table III.

TABLE III—The Effect of Heavy Watering on the Toxicity of 2,4–D to Sweet Corn

Treatments		Percentage Emergence	Malformation Rating*
Lbs 2,4-D	Watering		
	Golden Cross		
2	Heavy	85	6
2	Normal	85	4
4	Heavy	65	9
4	Normal	80	7
0	Heavy	75	1
0	Normal	80	1
	North Star		
2	Heavy	100	7
2	Normal	100	4
4	Heavy	85	7
4	Normal	95	5
0	Heavy	90	1
0	Normal	80	1

*1 = no injury, 9 = severe injury.

As indicated in Table III, heavy watering did not consistently influence percentage emergence but it in all cases increased the degree of malformation resulting from the 2,4–D applications. Although the injury is not as pronounced as that which occurred under field conditions when an extremely heavy rain came soon after treating, the data do indicate that rainfall might greatly influence the performance of 2,4–D.

Summary

The performance of sweet corn treated at 10 different stages of growth approximately a week apart indicated that the yield was not adversely affected by 0.4, 0.6, and 0.8 of a pound of 2,4–D acid to the acre. Experimental blocks treated at these rates on July 14 and July 21 produced significantly more corn to the acre in the husk than did uncultivated check plots. These fractional rates of 2,4–D gave commercial control of lamb's quarter, red-root and ragweed, although there were a few young seedlings of these weeds at harvest time in the first block treated.

Varietal response to foliage sprays of 1 pound of 2,4–D per acre were studied. Of the eight varieties studied, the growth of Seneca Dawn and North Star showed the most 2,4–D symptoms, whereas Lincoln and Ioana showed the least. Both greenhouse and field tests indicated that rainfall might influence the toxicity of 2,4–D to sweet corn when applied as a pre-emergence treatment.

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Some Studies Using Isopropyl N–Phenyl Carbamate As a Selective Herbicide[1]

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THE selective herbicidal effects of Isopropyl N–Phenyl Carbamate (IPPC) were clearly demonstrated by Templeman and Sexton (9). They stated that IPPC applied to the soil in amounts less than 2 pounds per acre prevented the growth of cereals and did not affect the growth of mangolds, sugar beet, flax, rape, or yellow charlock. Some workers have demonstrated that it is toxic to witchgrass (3, 7). This effect would suggest that IPPC may represent the counterpart of 2,4–D as a selective herbicide. In fact Allard *et al* (1) have found that a mixture of 2,4–D with IPPC proved to be an effective herbicide against young seedlings of both broadleaf and cereal species. Mixtures of these compounds, however, were not more effective on soybeans and oats than the compounds alone. Conflicting evidence has been reported by Taylor (8) who stated that 1 to 4 pounds of IPPC per acre did not influence dicotyledonous weeds and had only slight, temporary, inhibitory effect on weedy grasses.

Allard *et al* (2) found that IPPC was toxic to barley, oats, rye, wheat, and corn although it did not have any deleterious effects on such broad-leaved crops as sugar beets, kidney beans, cowpeas, turnips, radishes, soybeans, and sunflowers when applied at the rate of 80 pounds per acre. DeRose (4), however, showed that an application of IPPC at 50 pounds per acre was toxic to soybeans. It is generally recognized that IPPC is effective as an herbicide when it is applied to the soil and is relatively ineffective when applied to the aerial plant parts. DeRose (4) found that IPPC did not persist in the soil for more than 60 days.

According to Allard *et al* (2) the solubility of IPPC is only about 250 ppm and is attained only after vigorous shaking or stirring. The author has found that IPPC is readily soluble in Carbowax 1500, ethyl alcohol, isopropyl alcohol, acetone, and glacial acetic acid and as co-solvents these compounds are helpful in attaining the maximum concentration in a shorter time. Therefore, in concentrations greater than 250 ppm the IPPC is precipitated upon the addition of water to the IPPC and solvent. The physical nature of the precipitation is such that it clogs up a sprayer nozzle and the low solubility of this material does not make it economically feasible as a herbicide in a water solution. At present IPPC is quoted at $2.50 per pound to commercial houses, but this price will be reduced if a large commercial utilization results.

Allard *et al* (2) have stated that IPPC may be dissolved in twice its weight of tributyl phosphate (5), and the resulting solution is oil miscible in all proportions. Ennis (6) noted that tributyl phosphate

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itself had some herbicidal qualities which may or may not be desirable. Mitchell and Marth (7) found that 2 to 8 pounds per acre of IPPC mixed with quartz sand as the diluent was effective in controlling quack grass seedlings in plantings of sugar beets, table beets, carrots, radishes, onions, and spinach.

The purpose of this paper is to present further evidence as to the value of IPPC as a selective herbicide in several vegetable crops.

Experimental

Isopropyl n–phenyl carbamate was applied in rates varying from 2.5 to 10 pounds per acre in out-of-door plots as a pre-emergence spray on several occasions during the 1947 growing season. One method of applying the IPPC was to dissolve it in tributyl phosphate and then use Stoddard Solvent as the diluent. This mixture was ordinarily applied just after planting of the test crops, which included spinach, beets, carrots, lettuce, seed onions, and snap beans. Domestic rye grass was seeded in the plots to insure a potential stand of grass and this provided a heavy mat of grass in untreated plots.

The complete control of grass was especially noteworthy in all of the IPPC treated plots except at the 2.5 pound per acre rate and even here the stand of grass was negligible. It was particularly apparent, however, that there was an attendant increasing amount of damage with increments of IPPC. Spinach and particularly beans were not as susceptible to this damage as were the other crops. It was logical to assume that the damage was due to the IPPC until the plots which received a treatment composed of the tributyl phosphate and Stoddard Solvent without IPPC were examined. The plants on these plots also displayed the characteristic toxicity, whereas those grown on plots treated with Stoddard Solvent alone were comparable to the plants growing on the check plots. This indicates that tributyl phosphate at 2 to 3 per cent strengths in Stoddard Solvent applied at the rate of 100 gallons per acre is toxic to some vegetable crops. A 1.2 per cent solution of tributyl phosphate in Stoddard Solvent proved to be very toxic when sprayed on carrot leaves, but they were not harmed when sprayed with Stoddard Solvent alone. Ennis (6) had earlier demonstrated that plants were injured by tributyl phosphate.

In another test some plots of spinach and beets were planted in a field where rye grass had been sown several days previously. IPPC was mixed with clean quartz sand and applied on the surface of the soil at the rate of 5 and 10 pounds per acre of IPPC immediately after the crops were planted. Both rates of application were effective in preventing the growth of grasses completely and the germination of the spinach and beets was normal in every respect (Fig. 1). It was clearly evident, however, that the IPPC had little or no effect on such broadleaved weeds as lamb's quarters, pigweed, galinsoga, and shepherd's purse. Essentially the same results were obtained in greenhouse beds, where plots of beets and spinach, 50 square feet in size, were treated at the rate of 5 and 10 pounds per acre of IPPC mixed with sand. The crops appeared to be comparable to those in the check plots

FIG. 1. Showing the selective effects of IPPC. Left, Domestic ryegrass controlled completely with an application of 5 pounds per acre. The spinach developed normally. Right, Check plot showing the heavy growth of ryegrass in the untreated plot.

in all respects. There was no development of grasses, but the broad-leaved weeds grew normally.

In some further greenhouse tests where plants were grown in flats it appeared that IPPC at 5, 10 and 20 pounds per acre rates caused a slight delay in the germination of beets, spinach, and beans. These plants were also slightly dwarfed as compared with those in the check flats. There is no apparent reason why the plants grown in this test reacted differently from those in earlier tests. Set onions did not display this response even at the 20-pound-per-acre rate of IPPC. In one of the flats where IPPC had been applied at 20 pounds per acre, a 1.0 per cent dust of the sodium salt of 2,4–D at the rate of 200 pounds per acre was also applied on the soil surface after the crops were planted. In this flat neither weeds nor crops developed except the onions that were produced from sets and here the stand of onion plants and their development were comparable to those in the check planting. This finding is not intended to be final in any sense of the word, but it may provide a fertile field of research because of the potential value to onion growers who use sets to produce their crop.

SUMMARY

This report corroborates the findings of earlier investigators that isopropyl n–phenyl carbamate is valuable as a selective herbicide in that it effectively kills grasses with little or no harm to broad-leaved

plants. Beans, spinach, beets and set onions appeared to be especially resistant to this compound. Tributyl phosphate as a solvent for IPPC proved to be toxic to several vegetable crops. IPPC supplemented with 2,4–D may prove to be a valuable combination for preventing weed growth in fields of set onions.

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The Herbicidal Properties of Certain Pure Petroleum Hydrocarbons (Preliminary Report)[1]

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THE use of petroleum naphthas for selective and non-selective weed control is receiving considerable attention by investigators. Furthermore, heavier grades of oils have been found to be valuable as insecticides and as carriers for insecticides. Various investigators have postulated and others have presented evidence to show that herbicidal properties of petroleum oils are dependent on the quantity of unsaturated or sulfonatable hydrocarbons contained therein. However, very little experimental work has been done with pure hydrocarbons.

Herbicidal tests were made of 31 pure hydrocarbons of aromatic, olefin, and paraffin series, ranging in boiling point from 80 degrees to 300 degrees C, representing those hydrocarbons found in petroleum naphthas. The tests were made under greenhouse conditions at 70 to 80 degrees F on young plants grown in 7½ by 11½-inch flats. A flat contained one 7-inch row of each of the following: peas, lettuce, spinach, carrot, onion, timothy. The chemicals were applied with hand-operated atomizers, and care was taken to obtain good coverage. At least two tests of two replications each were made for most of the hydrocarbons.

The results of the herbicidal tests are summarized in Table I. The hydrocarbons are listed in order of increasing boiling points. The conventional 1 to 9 rating system is used to evaluate degree of injury where 1 denotes no injury and 9 indicates complete, rapid kill. Type of injury was either acute "A" or chronic "C", as defined by Crafts and Reiber (1). Chemicals were designated "+" if tolerated only by carrots or by "—" if tolerated by no crop, and by ". ." if tolerated by all.

A study of Table I suggests that in general the three series might be given the following toxicity rating:

aromatics>olefins>paraffins.

Straight-chain paraffins were the least toxic. The cyclo paraffins, especially the double ring naphthenes, were markedly more toxic than the straight chain paraffins.

Boiling point appeared to influence the toxicity of each of the series of hydrocarbons. In general the hydrocarbons included in the boiling range from about 150 degrees to 275 degrees C were more toxic than those hydrocarbons boiling on either side of that range. The low boiling hydrocarbons evaporated from the plant surfaces more quickly than those falling in the boiling range of maximum toxicity. This may at least partially account for the latter's greater toxicity. Factors other than evaporation rate, however, must be responsible for the relatively

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low toxicity of the hydrocarbons in the boiling range above 275 degrees C.

Of the five hydrocarbons given a toxicity rating of 9, all except diphenyl-methane are characterized by the naphthalenic molecular structure. It seems probable then that the presence of naphthalene aromatics may be responsible for a large share of the herbicidal properties of certain petroleum fractions.

Olefins boiling above 250 degrees C and paraffins and aromatics boiling above approximately 280 degrees C produced chronic injury as opposed to acute injury for the lower boiling hydrocarbons.

Laboratory tests were made with 29 of the hydrocarbons to determine their toxicity to dormant and germinating vegetable and weed seed (2). Although none of the hydrocarbons were found to be lethal to dormant seed, their comparative toxicities to germinating seed were similar to their effects on foliage.

Studies with the pure hydrocarbons are being continued.

TABLE I—Summary of the Herbicidal Properties of Thirty-One Pure Hydrocarbons

Name of Hydrocarbon	Series	B.P. (Degrees C)	Toxicity		Carrot Tolerance†
			Rating*	Type**	
1. Benzene	Aromatic	80	1	..	..
2. Iso-octane	Paraffin	99	1	..	..
3. Methylcyclohexane	Cycloparaffin	101	1	..	..
4. Diisobutylene isomers	Olefin	101–104	3	A	—
5. Toluene	Aromatic	110.5	5	A	—
6. n-Octene–1	Olefin	121.5	3	A	—
7. n-Octene–2	Olefin	125	3	A	—
8. n-Octane	Paraffin	125.5	3	A	—
9. Vinyl-cyclohexene	Olefin	129–130	5	A	+
10. Ethylcyclohexane	Cycloparaffin	130.5	3	A	—
11. Xylenes	Aromatic	138–144	7	A	—
12. Isopropyl-benzene	Aromatic	152.5	7	A	—
13. n-Decene–1	Olefin	172	7	A	+
14. n-Decane	Paraffin	174	5	A	+
15. Tri-isobutylene	Olefin	175–180	5	A	—
16. Diethyl-benzene	Aromatic	180	7	A	—
17. Decohydro-naphthalene	Cycloparaffin	185–195	7	A	—
18. Tetrahydro-naphthalene	Aromatic	207	9	A	—
19. Triethyl-benzene	Aromatic	211	7	A	—
20. n-Dodecene–1	Olefin	213	5	A	+
21. n-Dodecane	Paraffin	216	1	..	..
22. Dicyclohexyl	Cycloparaffin	230	7	A	+
23. Methyl-naphthalene	Naphthalene Aromatic	240–245	9	A	—
24. n-Tetradecene–1	Olefin	250	5	C	+
25. n-Tetradecane	Paraffin	253.5	1	..	..
26. Diphenyl-methane	Aromatic	262.4	9	A	—
27. Dimethyl-naphthalene	Naphthalene Aromatic	264	9	A	—
28. n-Hexadecene–1	Olefin	280	5	C	—
29. n-Hexadecane	Paraffin	286.5	3	C	—
30. Amyl-diphenyl	Aromatic	290–300	1	..	..
31. Amyl-naphthalene	Naphthalene Aromatic	288–292	7	A and C	+

*Rating: 1 = no toxicity, 9 = complete, rapid kill.
**Type of toxicity: A = acute or rapid; C = chronic or slow.
†Tolerance: + = tolerated by carrot, — = tolerated by no crop, .. = tolerated by all.

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Production of "Pops" in Spanish and Virginia Type Peanuts As Affected by Nutritional Level and Balance Under Greenhouse Conditions

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IN an effort to add to the information on the causes responsible for "pops", the usual term for unfilled peanut pods, the authors recently carried on a series of preliminary or exploratory greenhouse experiments. Numerous workers have shown the importance of nutritional factors on the fruiting capacity of the peanut.

A series of investigations in North Carolina (2, 3, 4, 5, 6) have demonstrated that gypsum and lime additions to the soil have frequently increased yields of peanuts, reduced the number of empty pods, and thereby increased the shelling percentage. Potassium applications have often had just the reverse effect. The authors of the papers cited stated that calcium was the element responsible for the reactions obtained. Since all of this work was done under field conditions, and results were somewhat variable but fairly consistent, it seemed desirable to more clearly establish this evidence through nutrient solution cultures and to study the effect of added increments of calcium and potassium on the fruiting characteristics of the peanut plant.

EQUIPMENT AND METHODS

The work was carried on in a 40 foot by 50 foot greenhouse section at the Plant Industry Station, Beltsville, Maryland. Center benches only were employed in the tests. Light distribution on all sides of the plants was found to be relatively uniform. Day temperatures of 75 to 85 degrees F with liberal ventilation were maintained except when outside conditions caused them to go higher. Night temperatures were about 10 degrees lower.

White silica F grade sand procured from the Pennsylvania Glass Sand Corporation, Lewistown, Pennsylvania, was used as a root medium for the peanut plants. For the purpose of aiding in drainage, 2 pounds of ⅛-inch mesh sand of the same composition was placed in the bottom of each container. The containers were 3-gallon glazed earthenware jars, each with a ⅝ inch drainage hole. These drainage holes were covered on the inside of the jars with pieces of coarsely woven paraffin impregnated fabric to prevent the sand from escaping during the flushing of the jars. The interior of each jar was coated with asphaltum varnish to prevent the possible absorption of material from the jars. Each jar received 33 pounds of dry sand, enough to fill the jar to about 25 mm from the top after washing. The 100 jars employed in the experiment were filled and placed on the flat-top bench and repeatedly flushed with tap water and finally with distilled water. On April 1, 1946, the pots were numbered and their positions randomized for each of the two varieties used. Fifty pots were used for Spanish and the same number for the Virginia Bunch. Twenty-five treatments were included, with two pots of each variety to a treatment.

Four seeds carefully selected for uniformity were planted in each pot on April 1. A week later the plants were thinned to one per pot. Immediately after planting the seeds, each pot to receive nutritional treatment was flushed with 4 liters of the appropriate solution. The check pots were flushed with distilled water. The 4 liters of solution employed were sufficient to cause free flushing of each pot. Thereafter each jar received 2 liters of the appropriate solution twice weekly, on Mondays and Fridays. During the early stages of the growth of the plants, the 2 liters applied to each pot were sufficient to cause run-off through the drainage holes. Later, during warm weather after the plants had attained some size, it became necessary to use supplementary distilled water between the regular applications of nutrient solution. The quantity of distilled water applied was estimated as sufficient to cause run-off through the drainage holes at the next application of the nutrient solution. This was done for the purpose of keeping the pH of the root medium as nearly constant as possible. Under the favorable conditions existing in the greenhouse the plants developed rapidly and the experiment was terminated on July 17, 1946, 108 days after planting. In general development the plants compared favorably with those grown under field conditions. This and other similar experiments indicate that peanuts respond satisfactorily to greenhouse conditions, provided careful attention be given to insect control, particularly red spiders.

Nutrient Solutions

The nutrient solutions used were made up of the salts KH_2PO_4, K_2HPO_4, KNO_3, NH_4NO_3, $NaNO_3$, $Mg(NO_3)_2 \cdot 6H_2O$, $MgSO_4 \cdot 7H_2O$, $CaCl_2$, and $Ca(NO_3)_2 \cdot 4H_2O$. Predetermined quantities of stock solutions of these salts were added to sufficient quantities of distilled water to give the parts per million of the various elements indicated in Table I. Since pH has been shown to play a very important role in the absorption of various elements, the dibasic and monobasic potassium phosphates were used in quantities that formed an initial pH in the solutions between 6.5 and 6.8; and the balances between ni-

TABLE I—Parts Per Million of Elements in the Nutrient Solutions

Treatment	Nitrate N	Ammonia N	K	Ca	P	Mg	S	Na	Cl
7	85	5	90	10	5	25	0	32	18
8	85	15	90	10	5	25	0	16	18
9	85	25	90	10	5	25	0	0	18
10	85	5	170	10	5	25	33	32	18
11	85	15	170	10	5	25	33	16	18
12	85	25	170	10	5	25	33	0	18
13	85	5	90	30	5	25	0	32	54
14	85	15	90	30	5	25	0	16	54
15	85	25	90	30	5	25	0	0	54
16	85	5	170	30	5	25	33	32	54
17	85	15	170	30	5	25	33	16	54
18	85	25	170	30	5	25	33	0	54
19	85	5	90	60	5	25	0	32	108
20	85	15	90	60	5	25	0	16	108
21	85	25	90	60	5	25	0	0	108
22	85	5	170	60	5	25	33	32	108
23	85	15	170	60	5	25	33	16	108
24	85	25	170	60	5	25	33	0	108
25	157	25	170	60	5	25	33	48	0

trate and ammonia nitrogen were such that the pH of the solutions after application did not go above pH 6.5 nor below 5.0 as determined from the leachings obtained upon application of fresh nutrient solution to the pots. Preliminary experiments had demonstrated the necessity of carefully controlling the pH within these limits. When ammonia nitrogen had been used the pH dropped rapidly and to rather low values. These findings are in accord with other published results (1).

Minor elements were supplied in the form of sulfates of copper, manganese, zinc, and iron, while boron was supplied as boric acid. The amounts in ppm were as follows: Cu = 0.06, Mn = 1.00, Zn = 0.13, Fe = 2.00, and B = 0.10. Some sulphur was supplied with the minor elements; and additional sulfur probably came from the air, since visable deficiencies of this element could not be produced in preliminary tests.

Discussion of Data

In Table II the average yields of dry weight of the tops of the plants, the number of cavities (filled or empty) in the pods, and the number of seed found in these cavities are given. It is easily seen by comparing Tables I and II that the amounts of calcium supplied in the nutrient solutions played a very important role. Plants that received only 10 ppm of Ca in the nutrient solution produced no pods at all while those supplied with 30 ppm produced a few unfilled pods in the Spanish variety and no pods in Virginia Bunch. At 60 ppm of Ca both varieties responded with pods and nuts, but the Spanish variety gave by far the better yields of nuts, treatment for treatment. This difference between these two varieties is a well known observation in the field, that is, Virginia or large-seeded varieties produce more pops than Spanish varieties when grown on the same soil. The low yields of the

TABLE II—Average Yield of Dry Weight of Tops and Number of Seed Cavities and Seeds in the Pods

Treatment	Spanish 18-38			Virginia Bunch		
	Dry Weight of Tops (Grams)	No. Seed Cavities	No. Seed	Dry Weight of Tops (Grams)	No. Seed Cavities	No. Seed
7	68	0.0	0.0	72	0.0	0.0
8	62	0.0	0.0	58	0.0	0.0
9	50	0.0	0.0	46	0.0	0.0
10	98	0.0	0.0	88	0.0	0.0
11	106	0.0	0.0	94	0.0	0.0
12	96	0.0	0.0	112	0.0	0.0
13	68	2.0	0.0	67	0.0	0.0
14	56	2.5	0.0	55	0.0	0.0
15	86	4.0	0.0	76	0.0	0.0
16	115	0.0	0.0	120	0.0	0.0
17	120	0.5	0.0	102	0.0	0.0
18	114	4.0	0.5	116	0.0	0.0
19	67	80.0	12.0	77	7.0	0.0
20	63	113.0	35.5	67	25.5	5.0†
21	68	127.0	43.0	54	32.5	14.5
22	118*	66.0*	9.0*	115	0.0	0.0
23	118	82.5	12.5	143	19.0	0.0
24	118	94.5	31.5	109	13.5	3.5
25	117	115.0	60.5	120	19.0	0.5

*Represents only one pot as replicate 2 received one extra high Ca application by mistake.
†All shriveled and undeveloped.

large-seeded types except in Virginia and North Carolina and a few very restricted areas elsewhere, can be largely attributed to excessively large proportions of pops in the yield.

The absolute supply of Ca available to the plants is not the only factor that determines pop production (2, 3, 4, 5). Fertilizer experiments in the field have often shown that application of K increases pops and decreases nut yields. From the data given in Table II it again appears that the higher level of K produced poorer yields than the lower level of K at the same Ca level. Competition between K and Ca is well known in many other crops and this appears to be another case of this phenomenon. Whether the K depressed the absorption of Ca through competition during absorption or created a need for calcium in the plant by causing more vegetative growth is not clear — probably both.

It is not clear why increased yields of pods and nuts are found as the ammonia increases from 5 to 25 ppm and the sodium decreases from 32 to 0 ppm while calcium and potassium both remain constant. The sodium may depress calcium absorption more than the ammonia or the added increments of ammonia may produce pH levels more favorable for Ca absorption.

As to the effects of the various levels of Ca upon the growth of the plants the following notes seem significant. When no Ca was supplied in the nutrient solutions growth was severely stunted and growing points were decidedly malformed (treatments 1 to 6), and agree with work reported previously (6). At the lowest level of Ca supply (10 ppm) numerous pegs developed but failed to mature into pods, as an area about ¼ to ½ inch from the end of the peg first became discolored and them shriveled up. This section corresponds to the area of cell division immediately behind the ovary, which is in the tip of the peg. Calcium apparently became so limiting as to prohibit proper development of the peg. With the shriveling of the peg just behind the ovary, no pods were formed and the plants continued to bloom and peg profusely until taken up for examination. As more calcium was supplied in the nutrient solution, pod development occurred; but the young ovules failed to develop, unless the highest amount of Ca was supplied. Indications are that better seed production would have occurred at even higher levels of calcium than those given in this test.

Thus calcium plays a very important part in the development of vegetative parts, pegs, and ovules. The amount of calcium required in the nutrient solution or in available form in the soil to complete all of these stages would appear to depend not only on the absolute amount of calcium available, but also on the degree of competition of other cations and on the actual amount needed by the plant as determined by the growth allowed by the other elements supplied and absorbed. Thus an improper nutrient balance affects pop formation, and calcium is the element primarily responsible.

Summary

Pops have been produced in two varieties of peanuts under controlled nutritional conditions, the Virginia Bunch variety being more

sensitive than Spanish 18–38. The amount of calcium supplied to the plant in the nutrient solutions played a very important role, that is, the less the calcium the fewer the pods produced and the fewer the nuts in the pods that developed. The higher level of potassium produced a decrease in pods and pod filling in comparison with the lower level of potassium, which indicates competition between calcium and potassium. Although ammonia and sodium variables were present in the test, it could not be determined whether increased pod filling was associated with increased ammonia application or decreased sodium increments.

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An Experimental Study of the Effects of Certain Earthworms on Crop Production

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THE sale of commercially produced earthworms has led to controversial discussion about their effect on crop production. Earthworms supposedly aerate the soil, mix its constituents, improve its drainage and claims have been made that this soil conditioning, results in greater and earlier maturing yields and provides more vigorous, disease and insect resistant plants which require less fertilizer and water.

This experimental study was undertaken to obtain information on the effect of two types of earthworms on the growth of a limited number of herbaceous and woody plants.

LITERATURE

Literature regarding earthworms concerns their identification and classification and their effect upon soils. Gates (2, 3) and Olson (8) have published manuscripts regarding the identification and classification of earthworms.

Hopp and Hopkins (6) grew millet in crocks of soil, treated with both living and dead earthworms. Their results indicate that the physical activity of earthworms had no apparent effect upon yield, however, there was an increase in yield from the chemical effect of the bodies of the earthworms. To obtain such a benefit, a continued cycle of birth and death in the earthworm population must be maintained.

Hopp (4, 5) reports an increase in soil aggregation as a result of the presence of earthworms, but refutes a common layman conception that inorganic fertilizers are injurious to earthworms within the soil. The New Jersey Agricultural Experiment Station has reported experiments which show that heavy applications of fertilizers each year for 5 years were not harmful to the earthworm population.

Russell (9) grew rye and spinach in pots of soil in the greenhouse, part of which were inoculated with earthworms. The plants grown in pots containing the earthworms showed broader and darker green leaves, and the dry matter contained a higher percentage of nitrogen. Less water was required to keep the inoculated soil at the proper degree of moisture. An investigation of the soil at the end of the experiment, however, showed a total absence of earthworms. He concluded that the decomposing bodies of the earthworms were the source of additional nitrogen.

Olson (8) concludes that while earthworms are found in soils varying in pH from 4.5 to 8.7, they are most abundant in soils with a pH of 8.0, where the moisture content is 12 to 35 per cent and the organic matter content from 4 to 5 per cent.

MATERIALS AND METHODS

This experimental study was initiated at Ohio State University in March, 1946, and continued at the University of Connecticut in 1947.

Two types of earthworms were used in the 1946 experiment. The one designated hereafter as type A was dug from a decomposing apple pumace pile, and the other designated as type B was purchased from a commercial earthworm farm which advertised them as hybrids. Dr. T. H. Eaton, Jr. (1) helminthologist, at George Washington University, identified type A as *Allolobophora caliginosa* and type B as consisting partly of specimens of *Eisenia foetida* and partly of *Eisenia rosea.*

All the plots using earthworms were inoculated, according to recommendations made by the producers of the type B earthworms, by making holes, 10 to 12 inches deep, spaced about 4 feet apart. The holes were filled with water and after it had soaked into the soil, approximately 100 earthworms or capsules thereof, with a small amount of the medium in which they had been grown, were placed into the bottom of each hole, which were then filled with soil. Where casting were used, 1 tablespoonful was placed in each hole when the plants were set out. One handful of earthworm castings were also placed around each plant on June 25th. The soil in the 1946 tests was not sterilized and no fertilizer of any kind was added. Soil tests were made according to the Spurway method.

1946 annuals were grown in two 3 by 60 foot beds which were enclosed on the sides by a galvanized iron sheet to a depth of over 3 feet. Each bed was further divided into four 15-foot plots by the galvanized iron sheets. A silty clay loam was placed in the beds to the depth of the enclosing side walls. The individual plots were treated as indicated in Table I. Twenty plants of each of four annuals were planted in each of the plots in one bed on May 21, 1946. Seven Marglobe tomato plants were planted in each of the four plots in the other bed on May 25th.

1946 perennials were grown in two 20 by 20 foot concrete pits with 8-inch side walls extending to a depth of 6 feet or more. Wooden planking was used to separate the individual plots in these pits. The soil in these pits was a silty clay loam. In the west pit some new soil containing sod was added. Plots in these pits were treated as follows:

East Pit

E–1, Manure plot. A 2-inch layer of well rotted cow manure was incorporated by spading.

E–2, Check plot.

E–3, Manure plus type B worms: a 2-inch layer of well rotted cow manure was incorporated by spading. Approximately 900 type B worms or capsules were added June 25, 1946.

E–4, Type B worms. Inoculated with approximately 900 worms or capsules on June 25, 1946.

West Pit

W–1, Manure plot. A 2-inch layer of well rotted cow manure was incorporated by spading.

W–2, Check plot.

W–3, Manure plus type A worms: A 2-inch layer of well rotted

cow manure was incorporated by spading. Approximately 900 type A worms were added on May 18, 1946.

W-4, Type A worms. Inoculated with approximately 900 worms on May 18, 1946.

The plants used in these tests were well rooted cuttings of chrysanthemum, variety Christopher Columbus, *Pachistima canbyi*, *Taxus cuspidata*, and seedlings of *Viburnum molle*. Planting was done between May 23 and May 26, 1946. All plants in these plots were shaded, cultivated, sprayed, pinched and watered according to good commercial production practice, unless otherwise noted.

The 1947 experiments were conducted at the University of Connecticut where the plants were greenhouse grown. The same annual flowers as grown in 1946, dwarf Zinnias, *Phlox drummondi* and annual chrysanthemums, were grown in a ground bed 5 feet 4 inches by 32 feet 4 inches. The bed had concrete sides extending to a height of 1 foot above the walk. Sandy loam soil was used to a depth of 14 inches with a gravel layer beneath. The bed was divided by planking into five equal sized plots. The entire bed was steam-sterilized.

The plots were treated as follows: A 2-inch layer of well-rotted, steam-sterilized horse manure was spaded into plots 1 and 2. Four inoculations each of approximately 100 type B earthworms or capsules were made in plot 2 and also in plot 4 on April 28, 1947. Plot 3 was kept as a check. The only treatment given to plot 5 was the placing of 1 tablespoonful of earthworm castings in the bottom of each hole when the plants were planted.

The arrangement of the three different annuals was duplicated in all five plots. Each plot contained 18 zinnias, 10 *Phlox drummondi* and eight annual chrysanthemums, which were set out on April 29, 1947. The greenhouse was maintained at an optimum temperature of approximately 60 degrees Fahrenheit. The plants were cultivated and watered as necessary.

Another experiment conducted in 1947, consisted of growing petunia plants with and without the addition of earthworm castings to the soil. Twenty pink, single-blossom type plants were carefully selected for uniformity of size. These plants were started from seed on January 15, 1947, and potted with a greenhouse soil mixture on February 26, 1947. They were shifted to 3½-inch pots on March 28, 1947. Ten of the plants were kept as checks, while the other 10 were given a treatment consisting of the addition of 4 tablespoonfuls of earthworm castings to the top of the soil in each pot. All of the potted plants were placed on a raised bench in a well-lighted section of the greenhouse, at a temperature of 60 degrees.

During 1946 and 1947, measurements for comparative growth were recorded on all annuals. Four tabulations were made on the zinnias of the number of blooms per plant, the average diameter of the blooms, and the height of the plant.

The *Phlox drummondi* and annual chrysanthemums were allowed to grow to maturity, at which time all of the plants in each plot were carefully removed from the soil and their roots washed free of clinging

particles. Both the green and the dry weights were recorded on a plot basis.

Experiments with annual dahlias were conducted only during the 1946 season. Eight recordings were made of the number of blooms and the diameter of the blossoms per plot. Records on the perennial chrysanthemums were taken of the number of breaks per plant and the height of each plant.

At the beginning of the 1946 fruiting season, records were kept of the number and weight of the tomatoes from each plot. This practice was later discontinued when a condition developed wherein the fruit rotted prior to maturity. No data recorded on the growth and fruitfulness of tomatoes are reported here.

Aggregation analyses were made of the soil used in 11 of the 1946 experimental plots. Four, 50-gram samples were taken from each plot. The method employed was a modification of the Yoder (11) method. Four 189-gram samples of soil were taken from each of 11 plots for the porosity analysis. Treatment of the samples was an adaptation of the Leamer and Shaw (11) method.

At the conclusion of the 1947 experiment, a careful count was made of the earthworms remaining in the greenhouse plots by sifting the soil through a 3/16-inch mesh screen. Each plot was marked out into quarters, and the soil in one of these was screened down to the level of the gravel bottom of the bed. Further random samples were sifted from all except plot 2, which was completely screened.

Results and Discussion

The data recorded on the annuals during the 1946 and 1947 seasons are given in Tables I and II. During both seasons there was no discernible difference betwen any of the plots in respect to earliness of flower production or color intensity of the flowers. The zinnias in the 1947 greenhouse experiment were heavily infested with aphids in late June, with all plots showing equal susceptibility. Tomato plants in all plots were equally susceptible to diseases and insects, being badly infected with mosaic, aphids and fruit-rot.

In comparing the total number of blooms per plant of the 1947 experiment with those of 1946, consideration must be given to the fact that the 1947 crop was not allowed to remain in the beds long enough to complete the blooming season.

The data presented in Tables I and II indicate that there is no consistent trend in favor of any of the treatments on the basis of the criterion used. Furthermore, none of the earthworm inoculated plots gave consistently better results than control plants in 1946 or the manure treated plot in 1947. Earthworm castings appeared to be somewhat beneficial in respect to the green weight of zinnias in 1946 and 1947, but this difference was not apparent on the basis of the other growth measurements used or was it true with the other annuals.

The sterilized manure plot produced the greatest green and dry weights of the 1947 crop of chrysanthemums, with the castings being second. Since the plants from the manure plus the type B earthworms plot were the lowest in both green and dry weight, it would seem with

this plant at least, that no advantages are derived by the addition of the earthworms and they may be actually detrimental. It is also worth commenting that by actual count, the manure plus type B earthworms plot was the only one actually containing any quantity of earthworms at the end of the experiment.

TABLE I—EFFECTS OF EARTHWORMS AND CASTINGS UPON THE GROWTH AND YIELD OF ZINNIAS, PHLOX, CHRYSANTHEMUMS AND DAHLIAS. THE OHIO STATE UNIVERSITY, OUTDOOR PLOTS (PLANTED MAY 21, 1946)

	Type A Worm	Check	Type B Worm	Earthworm Castings
Zinnia (Dwarf Cupid)				
Average number blooms per plant	76.9	66.1	67.4	78.5
Average diameter of blooms (inches)	1.1	1.1	1.1	1.0
Average height of plant (inches)	26.7	25.5	25.5	25.1
Average green weight per plant (grams)	225.4	237.9	224.1	257.6
Average dry weight per plant (grams)	76.2	68.9	73.5	79.8
Phlox Drummondi				
Average green weight per plant (grams)	145.2	140.6	122.5	95.3
Average dry weight per plant (grams)	27.2	27.2	22.7	18.1
Annual Chrysanthemum (North Star)				
Average green weight per plant (grams)	299.4	294.8	226.8	217.7
Average dry weight per plant (grams)	47.6	47.6	43.0	37.6
Annual Dahlias				
Average number blooms per plant	31.3	27.3	32.4	13.5
Average green weight per plant (grams)	452.2	415.0	436.8	410.5
Average dry weight of tops (grams)	34.9	44.5	41.7	30.8
Average dry weight of roots (grams)	45.8	39.0	37.6	50.8
Number of roots per plant	8.8	11.3	9.3	8.6

TABLE II—EFFECT OF MANURE, EARTHWORMS (TYPE B) AND CASTINGS UPON THE GROWTH AND YIELD OF ZINNIAS, PHLOX AND CHRYSANTHEMUMS, UNIVERSITY OF CONNECTICUT GREENHOUSE PLOTS (PLANTED APRIL 29, 1947)

	Manure	Manure Plus Type B Worms	Check	Type B Worms	Worm Castings
Zinnias (Dwarf Cupid)					
Average number blooms per plant	18.8	14.2	17.7	20.2	19.4
Average diameter of blooms (inches)	1.3	1.4	1.2	1.4	1.4
Average height of plant (inches)	30.3	32.0	34.0	34.5	34.0
Average green weight per plant (grams)	423.2	455.9	340.7	415.5	471.3
Average dry weight per plant (grams)	57.3	61.2	51.7	64.0	63.5
Phlox Drummondi					
Average green weight per plant (grams)	106.6	102.1	129.3	104.8	113.4
Average dry weight per plant (grams)	10.9	10.4	12.7	11.3	12.2
Annual Chrysanthemum (North Star)					
Average green weight per plant (grams)	712.6	580.3	595.1	601.0	612.4
Average dry weight per plant (grams)	57.3	43.1	48.5	44.0	50.3

The following comparisons may be significant:

1. Of the 23 growth measurements on annuals in 1946 and 1947, the check plots gave results equal to or better than one or more of the treated plots in 17 of the comparisons.
2. Check plots gave as good or better results as earthworm castings in 13 of the 23 comparisons.
3. In 1946, check plots gave as good or better results as type A earthworm plots in 6 of the 14 comparisons.
4. In 1946, check plots gave as good or better results as type B earthworm plots in 10 of the 14 comparisons.
5. In 1946, plots inoculated with type A earthworms gave as good or better results than type B earthworm plots in 11 of the 14 comparisons.
6. In 1947, manure plots gave as good results as type B earthworm plots in four of the nine comparisons. In contrast, manure plots gave as good results as manure plus type B earthworm plots in five of the nine comparisons.
7. In 1947, plots to which earthworm castings were added gave better results than plots to which manure was added in seven of the nine comparisons.

Perennials:—All the plots of perennial chrysanthemums were equally infested with aphids and leaf-rollers. During one dry period, all of the plots were allowed to dry out to a point where the leaves of the chrysanthemums showed definite wilting. No noticeable resistance to wilting with any of the treatments were observed. The plots inoculated with earthworms crusted to the same extent and were equally difficult to cultivate as the check plots. The manure plots showed the least tendency to crust.

No noticeable differences were observed in the amount of growth or in the color intensity of the foliage at the end of the first growing season with the woody plants, *Pachistima canbyi, Taxus cuspidata* and *Viburnum molle.*

Records on the number of breaks and average height of the plants for the hardy chrysanthemums growing in the east pit are given in Table III. Records on the chrysanthemum plants growing in the west pit are not given because of a mixture in the variety planted. The results, however, were comparable to those recorded on plants growing in the east pit.

The data indicate that inoculation of the soil with the type B earthworms showed no appreciable improvement over plants grown in plots to which manure was added, in respect to the number of breaks per plant, and the average height per plant was actually lower. Manure treated plots to which type B earthworms were added gave the greatest number of bottom breaks, approximately 16 per cent more than either the manure treated or earthworm inoculated plots alone.

Petunias:—The results with the 1947 petunia plants grown in pots to which earthworm castings were added produced more breaks and were larger than the check plants. Two of the treated plants bloomed on April 25, while the first check plant bloomed April 27. Comparative

green and dry weights of the petunia plants grown under the different treatments were as follows:

	Check	Earthworm Castings
Average green weight per plant (grams)	17.8	38.1
Average dry weight per plant (grams)	2.7	6.1

Porosity and Aggregation:—The data compiled concerning porosity and aggregation of the soil in the various tests during 1946 are given in Tables IV and V. The results of this soil study of the annual plots are not entirely in accord with those made of the soil in the east and west pits. In general, with annuals, there was no significant change in total pore space or the capillary pore space except in the plot where type B earthworms were added. Here there seemed to be a significant increase late in the season. During the season there was a definite decrease in noncapillary pore space in all plots. This indicates that soil aeration became progressively poorer. Non-capillary pore space was higher in the earthworm inoculated plots than in the checks early in the season and this difference was maintained throughout the season.

TABLE III—Effects of Type B Earthworms, With and Without Manure, Upon the Height and Number of Breaks of Perennial Chrysanthemums

Plot Treatment	Average No. Breaks Per Plant	Average Height of Plant (Inches)
East Pit		
Manure added	30.0	21.4
Check	32.6	21.1
Manure plus type B worms	35.4	19.6
Type B worms	30.3	18.6

The data compiled on soils in the pits indicate no significant and consistent changes in porosity when similar treatments in the different pits were compared with each other. Where manure was incorporated the total porosity increased in three of the four plots, while there was practically no change in the other manure treated plot. No significant change occurred in the total porosity of the check plots. The incorporation of type B earthworms decreased total porosity while incorporation of type A earthworms increased it.

The per cent of capillary pore space showed some increase during the season in all of the plots except one of the checks. The greatest increase occurred where earthworms or earthworms and manure were added. The increase was somewhat greater where the type A earthworms were added. While there was some decrease in the per cent of non-capillary pore space where manure alone was incorporated, it was not great when compared with the striking decrease when both types of earthworms were added. The data would seem to indicate that while there may be a slight increase in capillary pore space where earthworms are added, any advantage here is more than offset by the decrease in non-capillary pore space. It is also worth noting that the non-capillary pore space was greatest where manure was added in the east pit, but in the west pit, early in the season, it was highest where type A earth-

worms were added, but late in the season, the non-capillary pore space was best in the check plot. No significant trends in per cent of aggregation or in the average diameter of the aggregates seem apparent.

In the annual plots the percentage of aggregation was high when type B earthworms were incorporated 10 weeks after planting but was no better than checks after 4 months. In both of the pit plots the percentage of aggregation at the end of the 4 months period was lowest where earthworms were added. The diameter of the aggregates was also lowest in the east pit where type B earthworms were added. No significant difference in the size of the aggregates existed between the plots in the west pit.

Soils in all the annual and perennial plots were tested at the start and at the end of the growing period in 1946. No consistent or significant changes were apparent in pH, available nitrates, phosphorus, potash or calcium under the different treatments. The addition of either type of earthworm or earthworm castings to the soil showed no consistent beneficial changes over the addition of manure.

TABLE IV—EFFECT OF EARTHWORMS, WITH AND WITHOUT MANURE, UPON THE POROSITY OF THE SOIL (OHIO STATE UNIVERSITY 1946, OUTDOOR PLOTS)

Plot Number	Treatment	Per Cent Non-Capillary Pore Space		Per Cent Capillary Pore Space		Total Pore Space	
		Aug 3	Sep 26	Aug 3	Sep 26	Aug 3	Sep 26
1 Annuals	Type A worm	27.5	23.9	30.5	30.8	55.5	54.8
2 Annuals	Check	19.7	14.6	30.9	31.8	50.6	51.3
3 Annuals	Type B worm	24.2	20.4	28.7	32.1	52.4	52.5
East Pit							
1 Perennials	Manure	24.5	21.9	34.2	35.4	53.4	57.3
2 Perennials	Check	15.5	18.7	34.1	30.8	49.6	49.4
3 Perennials	Manure plus type B worm	17.2	17.8	34.8	35.1	52.0	54.1
4 Perennial	Type B worm	18.6	11.9	33.8	36.0	52.5	47.9
West Pit (Top 18 to 24 Inches of soil, Newly Added at Beginning of Experiment, Contained Some Sod)							
1 Perennials	Manure	15.5	14.7	38.2	39.5	54.7	54.2
2 Perennials	Check	15.9	21.0	36.2	37.7	57.1	58.7
3 Perennials	Manure plus type A worm	17.6	16.4	37.4	41.9	54.9	58.2
4 Perennials	Type A worm	20.6	14.4	35.4	39.4	50.9	53.8

Worm Count — 1947 Annual Plots:—A careful sifting of the soil in the various plots after the crops had been removed yielded the following information:

Treatment	*Number of Earthworms*	*Capsules*
Plot 1—manure	0	0
Plot 2—manure and type B worms	1507	Many capsules
Plot 3—check	0	0
Plot 4—type B worms	5	0
Plot 5—castings	0	0

The five earthworms found in plot 4 were mature specimens. An estimated 80 per cent of the earthworms found in plot 2 were immature

specimens. Most of this abundant crop of earthworms was found in pieces of the well-rotted horse manure that had been spaded into the plot the preceding April.

TABLE V—EFFECTS OF EARTHWORMS, WITH AND WITHOUT MANURE, UPON THE AGGREGATION OF THE SOIL (OHIO STATE UNIVERSITY, 1946, OUTDOOR PLOTS)

Treatment	Per Cent of Aggregation		Average Diameter of Aggregates in Millimeters	
	Aug 3	Sep 26	Aug 3	Sep 26
Annuals—Bed 7				
Plot 1—type A worm	33.5	25.7	0.57	0.55
Plot 2—check	49.8	42.3	0.71	0.55
Plot 3—type B worms	67.2	40.5	1.09	0.62
Perennials—East Pit				
E1—manure	32.9	26.4	0.75	0.62
E2—check	60.5	26.4	0.77	0.57
E3—manure plus type B worms	51.8	26.7	0.85	0.73
E4—type B worms	41.5	21.5	0.64	0.43
Perennials—West Pit				
W1—manure	35.7	28.5	0.99	0.86
W2—check	31.2	34.6	0.77	0.86
W3—manure plus type A worms	36.0	28.0	0.96	0.81
W4—type A worms	33.1	25.5	0.87	0.88

SUMMARY AND CONCLUSIONS

From the work done by Gates (3) and from correspondence with another helminthologist (1), it appears that at least some of the so-called "hybrid" earthworms are in actuality merely specimens of *Eisenia foetida*, or in some instances, *Eisenia rosea*. Both of these specimens are commonly found in compost heaps, manure piles, and similar decaying materials, as is true of *Allolobophora caliginosa*, the other type of earthworm used in these experiments.

Scientific research reveals that hybridization of earthworms is a very difficult, if not an impossible, achievement. The only available record of actual hybridization that has come to the attention of the authors is that reported in Stephenson's (4) Oligochaeta wherein Harms, a German scientist, grafted the ovaries of one species into another. A few of these hybrids hatched out from the capsule, but none lived to reach sexual maturity.

At the termination of the 1947 experiment, the worms added to the soil plot had disappeared, whereas those added to the soil plus manure plot had increased 275 per cent. These results agree with the findings of Russell (9) and Hopp and Hopkins (6), that most of the earthworms added to a soil without substantial amounts of organic matter will die.

With the annuals grown in 1946 and 1947, there was no appreciable difference in the earliness of bloom or color of the flowers due to earthworm treatments. Regardless of the treatment, all plants seemed equally susceptible to insects and diseases.

On the basis of the number of blooms, diameter of the flowers and the green and dry weight of the annual plants, there was no consistent benefits derived from adding either type of earthworm or earthworm castings. Type A earthworms gave somewhat better results than the type B earthworms.

All plots of hardy chrysanthemums grown in 1946 were equally susceptible to insect attacks and to lack of water. Cultivation was required as often in the earthworm inoculated plots as in the check plots. Soils crusted less where manure was incorporated than in any of the other treated plots. The plants grown in the plot treated with type B earthworms showed no increase in growth over plants in the manure treated or check plots. The percentage of breaks on these chrysanthemum plants was significantly increased when earthworms were added to the manure treated plots but not when the earthworms were added to the check plot.

At the end of the second growing season there was no appreciable difference in amount of growth or in the intensity of foliage color of the woody plants in any of the plots.

The addition of earthworm castings to petunia plants definitely increased the number of breaks, over-all growth and green and dry weights. Soil tests showed that the nitrate nitrogen content of the castings was higher than the soil to which they were added.

Analysis of the soil in the annual plots indicated that none of the different treatments caused any appreciable change in the total and capillary pore space. There was a definite decrease in non-capillary pore space in all plots during the season. Non-capillary pore space was higher in the earthworm inoculated plots than in the check plots early in the season and this difference was maintained throughout the season. Type A earthworms proved to be superior to type B earthworms in this connection.

With the perennial plots, the incorporation of manure increased total porosity, during the season, as did the addition of type A earthworms, but to a lesser extent. The data presented indicate some increase, during the season, in capillary pore space by the addition of earthworms, but any advantage here is more than offset by the considerable decrease in the non-capillary pore space.

The percentage of soil aggregation in the perennial plots at the end of 4 months was the lowest where earthworms were added. The incorporation of manure was effective in maintaining a higher percentage of aggregation. The additions of earthworms were not effective in increasing the average diameter of the soil aggregates. In general, organic matter was more effective in increasing soil porosity and aggregation than was the addition of earthworms.

There appeared to be no beneficial effects, over manure, of the addition of earthworms in changing the pH or in increasing the available nitrate nitrogen, phosphorus, potash or calcium content of the soil.

On the basis of the data presented, it would appear that, under the conditions existing in these experiments, earthworms are not sufficiently beneficial to the production of herbaceous and woody ornamental plants to warrant their purchase. The type A earthworms were equally

or more beneficial than the type B earthworms. The results of these experiments, and others, indicate that earthworms will not persist in soil unless a high content of organic matter is maintained. If a high content of organic matter is maintained, there seems little need of adding earthworms.

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Controlling Quack Grass by Spraying with Ammate or Atlacide[1]

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QUACK grass, *Agropyron repens* (L) Beauv. (Witch Grass) is a very common and persistent weed in many places where cultivation is practiced. It can be completely eliminated by cultivation, but this is seldom done because the time and expense involved is too great. Spraying with a weed killer, as reported by Southwick (1) in 1945, looks promising since spraying is rapid and easy and should be cheaper than cultivation.

In the summer of 1946 a series of plots 50 square feet in area were laid out in an orchard of 3-year-old seedling apple trees, previously in sod. Ammate (ammonium sulfamate, $NH_2SO_3NH_4$, plus a chromate) was applied at the rate of ¾, 1, 1½ and 2 pounds per gallon on July 1, August 1, August 15, September 1, September 15, and October 1. At each date half the plots were treated at the rate of 1 gallon per 100 square feet and half at 2 gallons per 100 square feet. Atlacide (Sodium chlorate, $NaClO_3$ plus a deflagration agent) was applied August 8, August 18, September 6, September 19 and October 3 at the rate of 20 ounces per gallon. On September 6, September 19 and October 3 additional plots were treated at the rate of 30 ounces per gallon. On April 24, 1947, an estimate was made of the percentage kill of quack grass on each plot. On those plots where the kill was complete, or nearly so, there was little or no recovery later in the season except where the quack grass came in from the edges of the plots. The results are presented in Tables I and II.

The data show that a complete kill of quack grass can be obtained with Ammate any time after August 1 provided enough material is used. About October 1 appears to be the best time to make an applica-

TABLE I—PERCENTAGE KILL OF QUACK GRASS (WITCH GRASS) FOLLOWING APPLICATIONS OF AMMATE IN 1946. (ESTIMATE OF KILL MADE APRIL 24, 1947)

Date of Application	Jul 1		Aug 1		Aug 15		Sep 1		Sep 15		Oct 1	
Gal/100 Sq. Ft.	1	2	1	2	1	2	1	2	1	2	1	2
Concentration—lbs/gal												
¾	40	40	30	85	70	99	70	90	80	95	99	100
1	40	60	40	90	60	100	70	99	80	95	99	100
1½	30	90	30	100	80	100	70	100	90	100	95	100
2	20	95	50	100	90	100	80	100	90	100	100	100

TABLE II—PERCENTAGE KILL OF QUACK GRASS (WITCH GRASS) FOLLOWING APPLICATIONS OF ATLACIDE AT 1 GAL/100 SQ FT IN 1946 (ESTIMATE OF KILL MADE APRIL 24, 1947)

Date	Aug 8		Aug 18		Sep 6		Sep 19		Oct 3	
Oz/gal	20	30	20	30	20	30	20	30	20	30
	70	—	70	—	80	95	85	95	100	99

[1]Contribution No. 652 of the Massachusetts Agricultural Experiment Station.

tion because at this time a minimum amount of material is required. Applications of ¾ pound of Ammate per gallon of water or 1¼ pound of Atlacide per gallon at 1 gallon per 100 square feet resulted in a complete or nearly complete kill of quack grass.

Ammate up to 1 pound per gallon, applied at the rate of 1 gallon per 100 square feet is safe to use around apple, pear, plum and cherry trees 3 years of age or older. An experiment started in the summer of 1947 indicates that apple trees 1½ years after planting will tolerate considerably higher concentrations of ammate sprayed around them. On the other hand, this material when used around the peach and cultivated blueberry proved very toxic to both.

Atlacide appears to be safe to apply around pear, plum and cherry trees 3 years of age or older if not more than 1¼ pounds per gallon and 1 gallon per 100 square feet are used. Young apple trees will probably tolerate higher concentrations. This spray is toxic to cultivated blueberries when used around them.

Some of the advantages and disadvantages of these two sprays are:

AMMATE

Advantages	*Disadvantages*
1. Highly effective	1. Corrosive action
2. Readily soluble	2. Higher cost
3. No fire hazard	
4. Non-toxic to animals	
5. Rapid breakdown in soil	

ATLACIDE

1. Highly effective	1. Less soluble
2. Lower cost	2. Slight fire hazard
3. No corrosive action	3. Toxic to animals
	4. Slow breakdown in soil

Neither of these materials is selective. Both will kill practically all vegetation with which they come in contact

Ammate at 18 cents per pound will cost $58.81 per acre when ¾ pound per gallon and 1 gallon per 100 square feet are used. Atlacide at 9.5 cents per pound will cost $51.84 per acre if 1¼ pounds per gallon and 1 gallon per 100 square feet are used.

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Breeding of Ornamental Plants

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THE numerous varieties of flowers and ornamental plants now available to gardeners have mostly been developed by amateurs, flower seedsmen, and nurserymen. Many of the finest were introduced before 1900, and hence preceded the era of Mendelian genetics. Until fairly recently very little planned breeding of plants grown for flowers has been carried out. So much variation was available that any large group of seedlings almost always contained some new and desirable types. Spontaneous bud sports, fairly common in some flowers, were also a fruitful source of new varieties.

The rediscovery of Mendel's work greatly stimulated all plant breeding. It also provided a great incentive to cytological research. Within a relatively short time a considerable amount of data were secured, and the basic principles of genetics established. At the present time we have reached the point in flower breeding where rapid progress could be made if adequate facilities and support were available.

The flower breeder is no longer so concerned with inheritance of individual genes as with whole blocks of them. There may, of course, be exceptions as, for instance, when it is desired to introduce into an otherwise acceptable variety any mono-genic character, such as rust resistance in Antirrhinum (6). The chance of transferring just one gene, however, is practically impossible. Many other genes go along, either as members of the same linkage group or on one of the other chromosomes. Frequently some of these genes have a deleterious effect and may be very difficult to eliminate. There is also the possibility of changing the effect of a gene by introducing modifiers. In a paper now in preparation, Emsweller and Blodgett (10) report that when a double-flowered nasturtium is crossed with one bearing single flowers, several genes modifying doubleness are introduced with the single genom. Previously it had been reported by Eyster and Burpee (11) that the double flower of nasturtium was a simple recessive of singleness. It is now known that the F_2 double-flowered plants are not uniform for doubleness, but vary from 5+ to 9+ in the mean number of petals per flower. The double-flowered parent has a mean petal count of 10 to 11. Plants with petalage equal to the double parent may be secured by continuous selection of those plants bearing flowers with the highest petal counts in F_2 and subsequent generations. The same results may be attained more rapidly by continued backcrossing to the double-flowered parent. There probably are similar situations in other plants that a more careful classification of F_2 phenotypes would uncover.

The flower breeder in the United States is confronted with the problem of adaptability to widely differing regions. Essentially this means breeding for different photoperiods, temperatures, soils, disease and insect resistance, and moisture conditions. These specialized problems in flower breeding require a careful and thorough search of all the genetic material available. They would be greatly aided if we could secure other varieties and closely related species from all foreign

sources. The importance of foreign plant introductions should be more widely recognized and provision made for adequate support. It is also true that a flower may be very fine in one location but often decidedly inferior in another region. Until the breeder has available trial plots in all sections of the country he is certain to discard many plants that would prove to be well adapted elsewhere.

From the point of view of techniques used it is convenient to divide flower breeding into the following sections: (a) sexually propagated plants, (b) asexually propagated plants, and (c) induced polyploidy. The first two groups are based on the commonly used methods of propagation. In some instances a particular plant may be increased by either sexual or asexual means.

In those flowers propagated by seed, high fertility is a prime requisite. It is also very important that a new variety be homozygous for such characters as flower color, plant height, time of bloom, flower shape, and to a lesser extent type of foliage. These are the most important characters in commercial flower growing and in formal bed plantings.

Most flower breeding with sexually propagated plants has been confined to selections of single plants followed by row trials and continued selection and trial until the required uniformity was attained. This method merely takes advantage of the variability already existing within a group of plants. It is more efficient if the single-plant selections are self-pollinated by isolation under cages or bags. As a rule, from three to five generations of inbreeding will produce acceptable commercial uniformity. This would, of course, vary depending on the genotype of the original selected plant.

When it is desired to combine some character, such as disease resistance of an unattractive plant, with a more desirable genotype the flower breeder must resort to cross-pollination. Considerable time will be saved if the two parent plants are fairly homozygous. It is also very helpful to know the genes that have already been identified in the parents. When two genotypes composed of many different genes are combined in a hybrid, the chances of securing new types by gene recombinations and interactions are very great. The new plants must be made fairly homozygous by inbreeding, and this may require considerable time and space. Occasionally an amateur breeder may select and try to purify a heterozygote. This frequently happens in the case of breeders who do not understand incomplete dominance. They may try for several years to develop a homozygous pink even though they secure a ratio of 1 red : 2 pink : 1 white in the F_2 generation.

A flower-breeding problem that has long baffled many breeders is the inheritance of doubleness in *Mathiola incana*. The problem is complicated by the presence of three types of single-flowered plants. One, when self-pollinated, produces all single-flowered individuals; the second, singles and doubles in the ratio of 3 singles to 1 double; and third, an approximate 1 : 1 ratio of singles and doubles, with the latter always predominating in the ratio of about 54 to 56 doubles to 46 to 44 singles. This latter form is called an eversporting single and is the one that produces the type of seed desired by florists and gardeners.

It has been assumed that a gene closely linked with the gene for single flowers is lethal in pollen grains and only very slightly so in the egg cells. A single-flowered plant heterozygous for the single-double gene pair and also carrying the lethal in the single-gene chromosome would produce only pollen grains carrying the double gene. The eggs being of two types, a little less than one-half having the single gene and a few more having the double gene, the F_2 population ratio would be about 1 to 1 for singles and doubles.

Since it is relatively easy to establish eversporting single plants by line testing, it has always seemed to me that the flower seedsmen should handle Mathiola as a perennial. An established field composed solely of eversporting single plants would produce large seed yields and at the same time eliminate the annual worry as to whether the percentage of doubles would hold up. Having only single-flowered plants in the field would save labor now used to care for the double-flowered plants that occupy over half the space, and yield no seed whatever. *Mathiola incana* is a member of the Cruciferae, having the winter hardiness common to this family. While I was working in California I carried over a small planting of Mathiola for several years. Each succeeding year the seed yield was much heavier than the first season. When I once suggested this plan to an amateur breeder he replied that he was afraid he would lose his type since he could not select each year. Unless the method proves not to be economical, it would go far in solving the problem of maintaining a uniform percentage of doubles.

Another technique that is just coming into use in flower breeding is the utilization of hybrid vigor. When two plants of different lines are crossed with one another, the resulting hybrid is often more vigorous than either parent. If the two parent plants are homozygous, the hybrids will be very uniform. The chance of obtaining greatly increased vigor usually increases the more the parent plants differ from each other. Thus more vigor and larger flowers could be expected from crossing a tall, red-flowered Antirrhinum with one that was short and bore white flowers, than from crossing two tall reds. As a rule, a considerable number of potential parent lines should be inbred for five to seven generations. All possible combinations should then be made until the best was determined. From then on the breeder need only maintain his chosen inbred lines and make the hybrids whenever he wished. As long as he maintained control of his inbred lines he would have a monopoly of the hybrid produced. At the present time florists are willing to pay good prices for high-quality seed, and the development of such inbred lines and hybrids should prove profitable. This method is only feasible with sexually-produced plants, and especially those that produce many seeds per fruit.

The flower breeder should constantly be watching for the appearance of male-sterile plants. In highly cross-pollinated plants, male sterility would be very desirable in producing hybrid seed, since it would eliminate all hand pollination. Male sterility may cause a plant to produce shriveled or vestigial stamens, or the stamens may develop fully but the anthers contain no pollen. These types of male sterility

are easy to recognize. It is possible that pollen may be formed and be non-functional. Such type of sterility is more difficult to detect.

Breeding for disease resistance in flowering plants has thus far not received much attention. Resistance to rust in Antirrhinum was shown to be a simple mono-genic dominant and the gene responsible was found in several species and races (6). It is almost impossible to control some virus diseases, such as aster yellows, and fleck and rosette of Easter lilies. Among the fungus diseases in the same category are Verticillium wilt of chrysanthemums and Fusarium rot of lilies, gladiolus, and narcissus. Resistance to any of these would be a valuable contribution. It is already known that some varieties of chrysanthemums are resistant to Verticillium, and certain varieties of lilies, gladiolus, and narcissus are resistant to Fusarium. It is also known that the fungi causing these diseases produce new strains that are capable of attacking varieties previously considered resistant. In some sections of our country it is almost impossible to grow many kinds of flowering plants because of the high incidence of leaf-spot diseases, soil fungi, and nematodes. An intensive search for resistance to these diseases would almost certainly prove successful. Such work requires close cooperation between the geneticist, plant pathologist, and nematologist.

The list of flowers and ornamental plants that are propagated asexually is very extensive. Among the more important of the flowers are roses, carnations, chrysanthemums, poinsettias, geraniums, hydrangeas, gladiolus, narcissus, hyacinths, tulips, lilies, iris, dahlias, and hemerocallis. Many of the perennials used in borders, such as phlox, delphinium, and gerbera, also belong in this group. All the flowering shrubs and ornamental evergreens also are found here. Practically all these plants are either highly or partially fertile, but most of them are so heterozygous that propagation is generally more satisfactory by asexual means. In some instances, even though seedlings might be acceptable, a plant is more rapidly increased by cuttings or by budding or grafting on a suitable understock. In all these plants high fertility is not important. Sterility may be desirable, especially if it increases longevity of the flowers. It is, of course, necessary that some seed be secured, otherwise variability would depend solely on fortuitous bud sports. As a rule breeding work with this group of plants is handicapped by all sorts of incompatibilities. When, however, a desirable plant is secured it may usually be increased rapidly by asexual methods and remain true to type except for mutations, and these may also be increased if they are worth while.

With the exception of the carnation, little is known concerning the inheritance of genes in the whole asexually-propagated group of flowering plants. The commercial type of double carnation is known to be the F_1 heterozygote between the super-double and single types. This was first shown by Norton (17) who published an abstract in the 1904 PROCEEDINGS OF THE AMERICAN SOCIETY FOR HORTICULTURAL SCIENCE on inheritance of doubleness in the carnation. All F_1 plants were commercial doubles in his crosses between singles and super-doubles, and in the F_2 generation the ratio was 1 single to 2 commer-

cial doubles to 1 super-double. The super-doubles are incompletely dominant to single and it is impossible to secure lines that will breed true for the commercial double type.

More recently Mehlquist (15) has published on the inheritance of color in carnations. He identified six independent factors concerned with self colors. Three of these are basic: Y controls the development of yellow anthoxanthin; I is epistatic to Y and controls the development of ivory anthoxanthin; A is the basic anthocyanin factor and is effective only in the presenec of both Y and I. All three of these factors are necessary for the normal production of anthocyanin. The other three factors are specific for anthocyanin, and with their alleles are responsible for the various colors and shades, excluding yellow and white, that are in the acyanic group controlled by the Y, I, and A genes.

Many of the finest varieties we now have among asexually-propagated plants originated as spontaneous mutations. Research on the mode of origin of these chance mutants is greatly needed. What is their nature, and what are the factors responsible for their appearance? In some ornamentals, such as carnations and chrysanthemums, mutations occur with a fairly high frequency, especially in some varieties. A cytological approach to this problem should be made. Possibly somatic non-disjunctions may be found, or somatic crossing-over with resulting deletions or translocations. Research of this type may also lead to development of methods to induce such mutations.

At the present time the breeding of most asexually-propagated ornamentals is of the so-called "plant and pray" method. Some reasons for this are the complete lack of genetic data and the general heterozygosity of the plants. They propagate so easily by asexual means that it has not been worth while to try to make them homozygous. Breeding chrysanthemums is a good example of this entire group. Here is an ornamental of considerable importance to florists, and also widely grown in home gardens. New varieties are listed each year in fairly large numbers, and certainly no one can deny that today's varieties are superior on the whole to those of 10 years ago. A steady improvement has taken place ever since chrysanthemum breeding was started in this country about the middle of the last century. All this has been accomplished without information on a single gene in these plants.

The origin of the modern chrysanthemum is unknown. The present-day varieties, as shown by Mulford (16), are heterozygous for numerous characters. He self-pollinated several varieties and secured a wide range of colors, flower types, and blooming dates from each selfing. This has been the common experience of all chrysanthemum breeders, and if a few promising seedlings are secured in a thousand, the percentage is considered good.

Chrysanthemum improvement could be greatly aided if data were available on the progenies resulting from crossing and selfing our present-day varieties. The important items that would be especially helpful include the type and color of flower for each seedling plant, and the frequency of desirable plants in each population. Such data

would also show what varieties were self-fertile and their cross-compatibility with other varieties.

Very often the plant breeder finds that self-and cross-incompatibilities form insurmountable barriers to securing seed. This is the situation in the genus Lilium, where repeated attempts to self-pollinate some species and varieties, or to secure certain hybrids, have uniformly met with failure. These difficulties have been overcome in some lilies by applying a hormone to the base of the pistil at the time of pollination (9). The hormone giving the best results was 1 per cent naphthalene acetamide in lanolin. A very small amount was applied to a wound made at the base of the pistil by tearing a petal just where it was attached to the receptable. In certain species crosses fruits were formed only when the hormone was used, none were formed on the checks. In some of these crosses the fruits contained seed. In other crosses, while fruits were set both on the check plants and those treated with the hormone, seed was secured only from the treated flowers. The Creole variety of *Lilium longiflorum* has always failed to form fruit when self-pollinated, but by use of the hormone we have been able to secure fruits in over 95 per cent of the selfings, and about 10 per cent of these have contained viable seed. In some crosses and self-pollinations large fruits are formed by the hormone treatment, but no seed has yet been secured. Probably some cross-pollinations are so genetically incompatible that even though a fruit is furnished by the hormone, the two chromosome sets are unable to form a zygote. There are also certain cross-pollinations in which the seed set has been less in the hormone-treated crosses than on the non-treated checks. Further work is needed to test other hormones as well as species in other genera.

Now that polyploidy can be induced artificially by using colchicine, the flower breeder has another tool available that as yet has received little attention. Considerable information is available that spontaneous polyploidy has been an important factor in the development of many of our finest ornamental plants. In narcissus, the best of the large-flowered trumpet varieties are tetraploids. These include King Alfred and Van Waveren's Giant. Both were derived by some sort of spontaneous doubling of the chromosomes, and were not known to be tetraploid until long after they had become well-established varieties.

In gladiolus, Bamford (1) has shown that all the present-day, summer-blooming varieties are tetraploids with 60 chromosomes. The basic chromosome number in this genus is 15, and the various species show the following number: 30, 45, 60, 75, 90, 120, and 138±.

Lawrence (13) found that garden dahlia varieties are octoploids with 64 chromosomes. This genus has a basic chromosome number of 8, and most of the species are tetraploid. Lawrence concluded, as a result of his studies, that *Dahlia variabilis* is a hybrid octoploid derived from the crossing of two tetraploid species followed by doubling of the chromosomes.

The basic chromosome number in the genus Chrysanthemum is 9. Many of the species are diploids with 18 chromosomes, others are triploids with 27, tetraploids with 36, hexaploids with 54, octoploids

with 72, and decaploids with 90. The few cultivated chrysanthemum varieties in which chromosomes have been counted are all hexaploids or aneuploids of hexaploids (3). The fact that chrysanthemum varieties are hexaploid, or nearly so, explains their extreme heterozygosity.

The situation in bearded iris is especially interesting. Here Randolph (19) has shown that practically all the older varieties introduced from 1840 to about 1910 are 24-chromosome diploids. From this latter date on there has been a remarkable shift to tetraploidy. The first tetraploids began to appear soon after the introduction into Europe, toward the end of the last century, of Asiatic and Eastern Mediterranean species and collected varieties of tetraploid iris. In 1942 and 1943 lists were compiled of the best varieties as judged by iris fanciers. The chromosome number of 109 of the 121 receiving the most votes was determined, and 108 of these were tetraploid and one was triploid. Not a single diploid existed among this selected group of varieties. They were selected and introduced as varieties because they were of superior quality and not because they were tetraploids, since the originators did not know the chromosome number. The shift from diploids to tetraploids occurred between 1910 and 1943.

It appears, then, that during the development of our modern varieties of chrysanthemums, dahlias, gladiolus, narcissus, and iris, man has been selecting polyploids because they are definitely better than diploids. There are many reasons for this. As a rule polyploids have larger flowers, more vigor, and flower later in the season than diploids. We still have many flowers and shrubs that would be greatly improved if the flowers were somewhat larger. There are some that need stiffer, more wind-resistant stems. In some sections the flowers of many spring-flowering shrubs are frequently severely damaged by late frosts. If we could produce later-flowering tetraploids, this damage would be reduced or eliminated and the flowering season also extended.

It is very foolish to assume that all plants can be improved by doubling their chromosome number. It has already been pointed out that gladiolus, chrysanthemums, dahlias, iris, and some narcissus varieties are already polyploid. Further doubling their chromosome number is more likely to be detrimental than productive of any beneficial results. Even in the case of diploids there is no assurance that doubling the number will necessarily bring improvement.

When the chromosome number of a diploid is doubled the resulting plant is called an autotetraploid. As a rule autotetraploids are rather sterile. This is a serious handicap when the plant can be propagated only from seed. In some diploid flowering plants, such as Antirrhinum and Papaver, each fruit produces a large number of seeds. Even though fertility is reduced by 50 to 60 per cent, if an autotetraploid of these plants is desirable, the reduction in seed yield is not too serious. In most flowering plants the cost of seed is a minor factor in producing a crop, and most florists and gardeners are willing to pay well for superior varieties.

If autotetraploids are to be made of seed-propagated plants the diploid lines should be inbred long enough to secure homozygosity for

flower color, height of plant, time of blooming, and other important characters. If this is not done, the breeder will have difficulty in fixing his tetraploid lines because he will be dealing with tetraploid segregations and will find it necessary to grow large populations.

While sterility is usually expected in autotetraploids, it is by no means their normal condition. In Antirrhinum autotetraploids now being developed at the Plant Industry Station, Beltsville, Maryland, Pryor (18) finds considerable variation in fertility. While some are almost completely sterile, others vary in fertility from low to relatively high. Some of the most fertile lines arose from doubling the chromosomes of inter-varietal hybrids. This strongly suggests that they may be approaching the behavior of amphidiploids. An amphidiploid is secured when the chromosomes of an interspecific hybrid are doubled. Actually when two distantly related varieties of the same species are crossed, their tetraploid may behave very much like an amphidiploid. This is a potentially fertile field for investigation in flower breeding. It would require that highly inbred and distantly related varieties be crossed and these hybrids then treated with colchicine. Very likely it would be necessary to select the most fertile individuals and by inbreeding gradually make them commercially homozygous.

Levan (14), in reviewing the present state of plant breeding by induction of polyploidy, pointed out that induced polyploids should be considered not as finished products but as raw material for further breeding. In those forms regularly propagated by seed it is necessary to produce a large number of polyploids of varying genotypes. It was also found in Sweden that polyploids of cross-fertilized plants were more promising than those of normally self-fertilized types. In addition, tetraploids of plants cultivated for their vegetative parts were much better than of those cultivated for their seeds.

Meiotic irregularity in autotetraploids has been suggested by Darlington (2) and Kostoff (12) as one of the reasons for their reduced fertility. A cytological comparison of sterile intra-varietal and fertile inter-varietal tetraploids of *Antirrhinum majus* made by Sparrow, Ruttle, and Nebel (20) showed no significant difference in major meiotic irregularities. This indicates that the inter-varietal hybrids are not behaving as amphidiploids, and their increased fertility cannot be explained on this basis. Possibly their greater vigor and reduced homozygosity may account for the increase in seed yield.

As a rule, flowers soon fade and deteriorate after pollination and fertilization. For this reason sterility may be an asset in the production of cut flowers. Since seed-setting is of no importance in asexually-propagated plants, the possibilities of tetraploidy with them should be thoroughly explored. In Lilium, Emsweller and Brierley (7), Emsweller and Lumsden (8), and Emsweller (4) have made some progress in inducing autotetraploids. It has been demonstrated in *Lilium longiflorum* that considerable variation may be expected between tetraploids of different seedlings. Some are of very superior quality and others show little or no improvement over the diploid type.

In *Lilium longiflorum* a few aneuploids were also secured from the colchicine treatments. These are $4n - 1 - 1 - 1$, $4n - 1 - 1$, $4n - 1$,

and 4n + 1. The chromosomes of *L. longiflorum* are large and 8 of the 12 types are easy to recognize because of differences in length, position of centromere, or presence and location of secondary constrictions. The remaining 4 are almost isomorphic, but it is possible to differentiate at least 2 types. It is therefore possible to identify all missing or excess chromosomes. One of the most attractive lilies so far secured is a *L. longiflorum* 4n − 1 − 1 − 1. The missing chromosomes are all different, so the plant is tetrasomic for 9 chromosomes and trisomic for 3.

A potentially fertile field for investigation in flower breeding is to make species hybrids and then double the chromosomes to make amphidiploids. As a rule, species hybrids are rather sterile and there is considerable chance the doubled hybrid will be fertile. In Lilium, Emsweller (5) has secured two amphidiploids. In one, x *Lilium testaceum*, a hybrid between *L. candidum* and *L. chalcedonicum*, the chromosomes pair very irregularly. The second hybrid is between *L. myriophyllum* and *L. Henryi*. Nothing is known regarding chromosome pairing in it. Neither amphidiploid has flowered as yet, but it is hoped both will prove fertile.

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FIG. 1. Gardenia flower buds: (a) normal bud, (b) peduncle after abscission of the corolla tube, (c) and (d) buds in the process of abscission. Note the white edges of the petals of flower bud in (d) and the ring of discolored tissue around the base of the peduncle in (c).

Buds with corolla tube removed and kept 70 degrees required 10 to 12 days.

Buds with corolla tube removed and kept 80 degrees F required 8 to 9 days.

ANATOMICAL ASPECTS OF THE ABSCISSION PROCESS IN THE PEDUNCLE OF THE FLOWER BUD

The first evidence of an abscission zone in peduncles of treated flower buds was on the seventh day after treatment. The zone was found in peduncles of flower buds treated with vaseline and kept at a temperature of 70 degrees F, and also in peduncles of buds treated by removing the corolla tube and kept in a temperature of 70 degrees F. This zone of cells did not lie at the exact point of junction of the peduncle and stem. It was in the base of the peduncle, approximately 3 millimeters from that junction.

The abscission zone appeared as a zone of cells 4 to 6 tiers thick in the cortex, and 6 to 8 tiers thick in the pith. This zone began in the epidermis and extended across the cortex to the vascular tissues. It did not extend across the vascular tissue, but it did extend across the pith. The zone apparently originated independently in the epidermis and cortex, and simultaneously in the pith.

The cells in the abscission zone had thicker cell walls and were slightly more rounded than the cells outside of this zone. The cells in

the tissue of the abscission zone were parenchymatous, as were the cells of the surrounding tissue. The lamella of these cells were prominent, due to the change of pectic compounds in the middle lamella of the cell walls.

On the ninth day after treatment (Fig. 2), the cells in the abscission zone began to separate in an irregular line, starting in the epidermis and extending into the cortex for a short distance. This separation involved one to two rows of cells, and appeared to be due to the dissolution of the primary cell wall and the middle lamella. The secondary cell wall did not dissolve and was seen as distorted pieces of tissue clinging to the tissue yet intact.

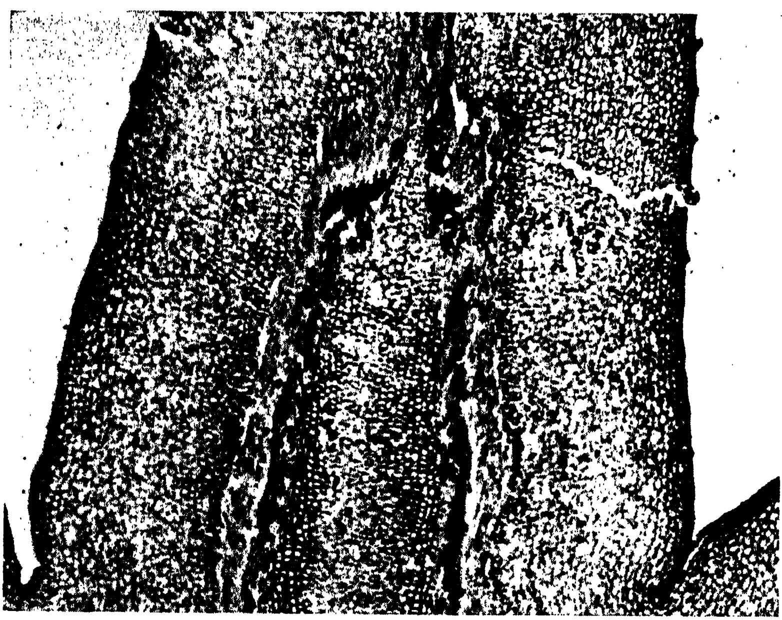

FIG. 2. A longitudinal section of a peduncle on the ninth day after treatment, showing the beginning of separation of cells through the cortex.

With the continued development of the abscission process, more cells in the abscission zone took part in the separation. On the eleventh day after treatment (Fig. 3) the abscission zone had increased in thickness, varying from 15 tiers of cells in the cortex to 9 in the pith. The cells of the epidermis had disintegrated in the area of this zone. As the abscission zone approached the vascular tissue, through the cortex, there was a decreasing number of rows of cells in it.

The cells in the abscission zone across the pith did not begin to separate at the same time as those cells in the cortex. After the cells of the cortex, endodermis, pericycle, and phloem separated, the parenchyma cells of the xylem and the pith then followed. This separation began

FIG. 3. A longitudinal section of a peduncle on the eleventh day after treatment, showing the further development of the abscission process.

in the parenchyma tissue of the xylem and proceeded toward the center of the pith. The complete separation across these cells was very rapid, occurring in approximately 24 hours.

The final stage of separation was the rupturing of the xylem vessels by mechanical force. Apparently, the amount of force necessary to rupture the xylem vessels was relatively small, because the weight of the bud was usually sufficient.

On the twelfth day after treatment (Figs. 4 and 5) and at the same time the flower bud had abscissed, a phellogen layer was found across the cortical tissue of the stem. The phellogen was a secondary meristem which was active in cell division. Cork cells were cut off by this meristem and they formed a protective cover over the injured tissue where abscission had occurred.

The actual separation of the cells of the abscission zone in the peduncle was preceded by some swelling and gelatinization of the pectic compounds of the middle lamella. Throughout the process of abscission there was seen no semblance of a preformed layer of specialized cells extending through the abscission zone, as is often found in the leaf-bases at the time of leaf-fall.

FIG. 4. A longitudinal section through the stem in the region where the flower bud had abscissed, showing the formation of a phellogen layer, a-a.

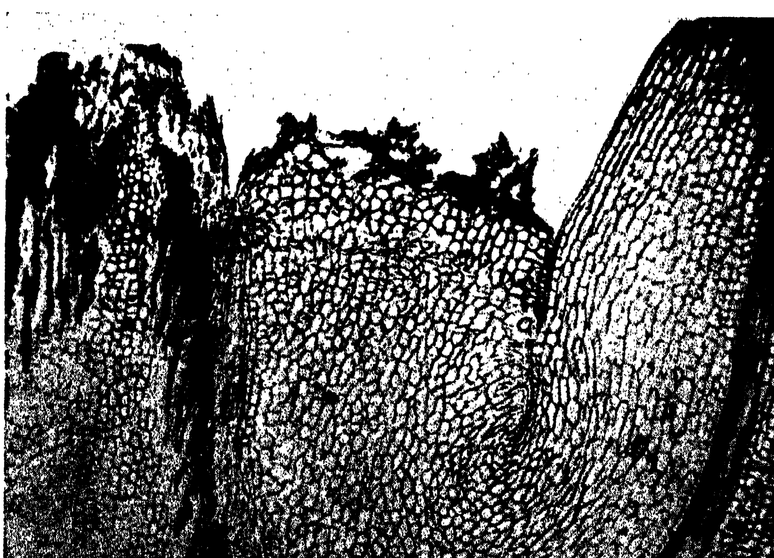

FIG. 5. An enlargement of the area labeled a-a in Fig. 4, showing the phellogen layer extending through the cortex.

Summary and Conclusions

Abscission of flower buds was induced by covering the buds with vaseline and, too, by removing the corolla tubes. Approximately the same length of time was required for abscission when induced by either method when the atmospheric temperatures were identical. An increase in atmospheric temperature decreased the length of time required for abscission. The first anatomical evidence of an abscission zone in the peduncle was on the seventh day after treatment. Separation began on the ninth day after treatment and appeared first in the epidermis and cortex. Final separation constituted the fracturing of the xylem vessels by mechanical force. This generally occurred on the twelfth day after treatment was given. A phellogen layer was formed across the cortical tissues of the stem. There was no specialized layer of cells through the abscission zone.

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Use of Growth Regulating Substances to Overcome Incompatibilities in Lilium

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The lily-breeding program at the Plant Industry Station, Beltsville, Maryland, has been concerned with developing improved forms of *Lilium longiflorum* and obtaining hybrids between species within the genus. The work has been retarded because of the widespread self-incompatibility encountered and the failure to get hybrids from most species crosses. In this paper results are presented on methods of overcoming self-incompatabilities in *L. longiflorum,* and procuring seed from some species crosses by the use of plant growth-regulating substances.

Self-incompatibilities in some species of plants present a serious obstacle to their further improvement by breeding. The literature on incompatibilities has been reviewed in detail by Stout (9). In self-pollinations and some intraspecific crosses the failure to set seed has been attributed to the action of specific genes. In general the effect of genes for self-incompatibility is to retard the growth rate of pollen tubes in the style. This results in either failure of the pollen tubes to reach the ovary or their reaching it after the ovules have degenerated. In either case no seed is formed.

The difficulties encountered in making species crosses are generally attributed to several causes. The pollen may fail to germinate on the stigma, or the pollen tubes may penetrate the style for only a short distance. The pollen tubes may burst within the style, or may grow too slowly to reach the ovules before they degenerate. Even if the tubes reach the ovarian cavity they may fail to penetrate the ovules; or, if penetration is effected, the two gametes may be unable to cooperate in forming a zygote. Instances may also occur in which a zygote is formed, but its development is arrested at some immature stage. Finally, an embryo may be fully formed, but no endosperm. Such embryos are not likely to survive unless artificially cultured.

As a rule, species hybrids are highly sterile. The amount of seed set varies with different hybrids, but rarely approaches that of the two parent species. Among the reasons most commonly cited for this sterility is the high frequency of chromosomal derangements during meiosis. These include failure of bivalent formation, multivalent associations, and chromatid bridges. As a result very few viable gametes are formed. In some sterile hybrids, however, pairing of chromosomes at meiosis is regular (Dobzhansky 3). The sterility in some species hybrids may also be due to the presence of incompatible genes. Baur (1), reporting on the species hybrid *Antirrhinum molle* x *A. majus,* indicated that two dominant genes for self-compatibility were present in *A. majus.*

In *Brassica oleracea* var. *capitata,* Pearson (7) has overcome self-incompatibility by bud pollination made from 1 to 5 days before anthesis. The increased fertility in cabbage from bud pollinations has been attributed to the longer interval available for the pollen tubes to

reach the ovules before they degenerate. Self-incompatibility in petunia has also been counteracted by bud pollinations (Yasuda 12, and Eyster 4). The pollinations were made on flower buds just beginning to develop anthocyanin in the petals.

According to Yasuda (13), the placenta of *Petunia violacea* secretes a "special substance" that diffuses into the style and retards or completely inhibits the germination of its own pollen and the development of pollen tubes, but permits pollen of other non-related strains to function. In 1941, Eyster (4) reported that seed was secured on a self-sterile strain of the petunia variety Golden Rose, presumably *P. violacea,* by use of a solution of alpha naphthalene acetamide applied as a spray on the flowers immediately before or shortly after they had been self-pollinated. It was assumed that the hormone neutralized the effects of the inhibiting secretion. Eyster also stated that preliminary experiments indicated that self-fertility or self-compatibility of highly inbred and highly sterile strains of *Tagetes erecta, Brassica oleracea,* and *Trifolium pratense* were greatly increased by the treatment.

In *Datura stramonium* and 4n *Melandrium dioicum (= Silene dioica),* Overbeek *et al* (6) were able to induce parthenocarpic fruits and enlarged ovules by injecting a 0.1 per cent solution or emulsion of the ammonium salt of naphthaleneacetic acid into the young ovaries. Untreated ovaries failed to develop fruits. In *D. stramonium* the enlarged ovules developed seed coats and often contained a pseudo-embryo consisting of several hundred cells. These pseudo-embryos originated by proliferation from the inner layer of the integument.

More recently Lewis (5) has shown that application to cherries of naphthalene acetamide either in aqueous solution or in lanolin smear did not stimulate fruit formation in the absence of compatible pollination. This was also true for plums and pears. In Oenothera an ovary smear treatment without pollination caused fruit to develop in every treated flower. Lewis summarized the published data on the stimulation of fruit development with chemicals. In many-seeded fruits, such as cucurbits, tomatoes, and Oenothera, fruits are stimulated. In few-seeded fruits, such as cherries and plums, fruits are not formed.

In Lilium, each of the named varieties and hybrids, some of which are classified as species, are members of a clone. Clonal groups also exist within some species. Many of these clones fail to set seed with their own pollen but function readily when pollinated by some plant not a member of the same clone. The Easter lily, *Lilium longiflorum,* is one of the species that has been reported to be composed of self-incompatible clonal groups by a number of investigators. Stout (8) reported on compatibilities in this species and found that self-incompatibility was common. Failure to set seed in most commercial varieties of *L. longiflorum* when self-pollinated was reported by Brierley *et al* (2). The varieties used were listed as tall and short Creole, tall and short Croft, Floridii, Erabu, and a stock of seedlings grown from open-pollinated Croft in Oregon. It is now known that the tall and short Creole and the Floridii were all the Creole variety. The tall Croft is now designated as the Estate variety. In the Creole variety 77 self-pollinations were made but not one fruit was formed. The Croft and

Estate clonal varieties and strains of the variety Erabu also proved self-incompatible. Selfed seed was obtained on 7 of the 43 plants of the giganteum variety of longiflorum and on 4 of the 51 mixed seedlings. The giganteum variety was imported from Japan before World War II, and the variability existing between plants indicated that it was not a clonal line. The mixed seedlings from the open-pollinated Croft variety undoubtedly were hybrids with other varieties of Easter lilies. In field trials in Louisiana no seed was obtained on the Creole variety from 200 controlled selfings, from 100 inter-crosses of 43 Creole plants, or from bud-pollinations of 100 flowers on the same 43 plants.

Materials and Methods

The longiflorum clones used were the Creole, Croft, and Ace. These have been propagated as clones for some years and are now recognized as well-established varieties. In the cross-pollinations 31 species or species hybrids of Lilium were used as seed parents, and 53 as pollen parents. Most of the species and species hybrids were in the lily collection of George Slate at Geneva, New York, who kindly permitted us to use his plants for this work. Some of the pollinations were made at our own planting of species at Lantz, Maryland.

All the longiflorum pollinations were made during the winter in screened, fumigated greenhouses. The outdoor pollinations on the other species and hybrids were protected from cross- or self-pollination by rigid emasculation of all flowers in the bud stage.

The hormones used were as follows: indolebutyric, indoleacetic, and naphthaleneacetic acid, naphthalene acetamide, beta naphthoxyacetic acid, mono-, di-, and tri-chlorphenoxyacetic acid. These were dissolved in lanolin at concentrations of 0.1 to 1.0 per cent. Each mixture was applied at the base of the style and also on the wound at the base of the ovary produced by removing one petal. Later it was found to be equally effective if applied only at the base of the ovary. On large trumpet flowers, such as longiflorum, a petal was not removed but merely broken at the base by the use of the thumb nail.

Results

The 1 per cent concentration of naphthalene acetamide proved to be the most effective material in all the pollinations. The application of hormones to the base of the ovary in self-incompatible Liliums had several marked effects on the developing ovary. There was a rather rapid swelling of the pedicel directly below the pistil, and abscission of the style was delayed over a period of several weeks. Occasionally aerial roots were developed from the bottom of the pistil. In species with pendulous flowers the young ovary soon assumed an upright position.

Self-Pollinations in Lilium Longiflorum:—Most of the self-pollinations in longiflorum have been on the clonal variety Creole. The first treatments were applied in 1940. A total of 86 seed with embryos were secured from several hundred self-pollinations. Bud-pollinations made without use of a hormone failed to produce a single fruit.

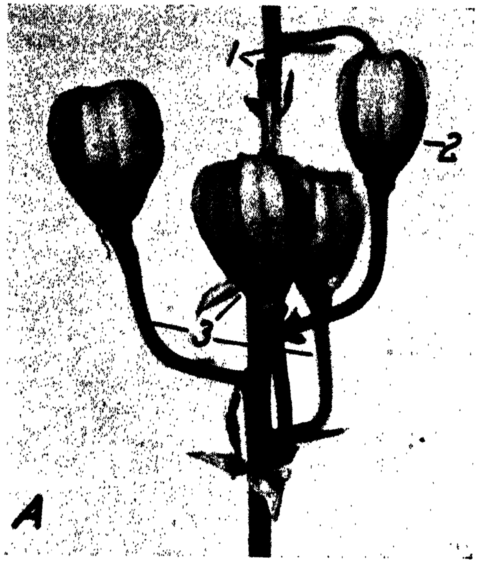
In 1946 another series of self-pollinations was made on the Creole clone. A total of 750 flowers were pollinated and of these 300 were treated with 1 per cent concentrations of naphthalene acetamide. No fruits were formed from the 450 untreated flowers, while 290 of the 300 treated ones had large fruits. Eighteen of these had 117 seed with embryos. The remainder were seedless. A fruit produced from treatment and an untreated check on the same clone are shown in Fig. 1B.

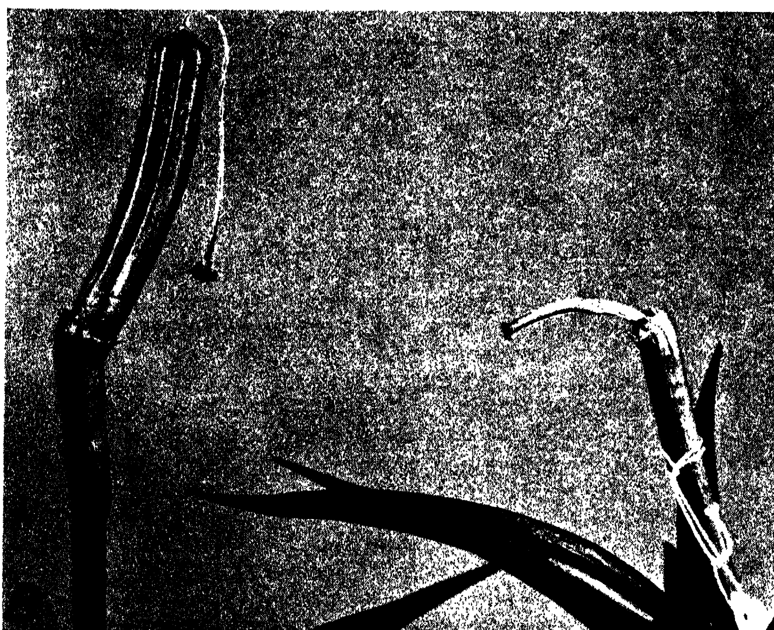
Since the Croft variety of longiflorum had always been self-incompatible, a series of treated and untreated self-pollinations was made on it in 1945. All of the 48 treated pollinations formed fruits and 6 of these produced 119 seeds with embryos. None of the untreated selfs set fruit. In the same year a similar experiment was set up with the Ace variety; 48 untreated pollinations produced 9 fruits with a total of 207 good seed. The 90 treated pollinations yielded 90 fruits, 45 of them producing a total of 2,414 good seed. The averages per fruit were 23 seed for the untreated, and 54 for the treated.

The seed formed on the selfed Creole and Croft varieties is the first we have obtained from self-pollinations of these two clonal varieties. In both instances the seed was very small, being less than half the size of seed secured on each clone when cross-pollinated by the other. The seed obtained by selfing the Creole variety in 1941 and seed from the cross Creole by Croft was planted on the same day. The latter germinated within a few weeks and produced vigorous seedlings. The former did not emerge until several weeks later and the seedlings were very weak. They grew very slowly and the difference between the crossed and selfed seedlings was so great that the latter were suspected of being haploids. A total of 12 were examined cytologically and all were diploid with 24 chromosomes. This unusual seedling population continued to grow very slowly and at the end of the first year produced bulbs less than one-quarter the size of the crossed seedling plants. The entire population was lost from a bulb rot, presumably *Fusarium oxysporum* f. *lilii*. The new population secured from the 1946 self-pollinations of the Creole variety is now being grown in vermiculite under more favorable conditions. The selfed Croft and Ace seedlings were vigorous and did not differ materially in vigor from any crossed populations grown at the same time.

Intra- and Inter-Specific Crosses:—A total of 86 different cross- and self-pollinations were made with lily species other than longiflorum. Seed was obtained from 47, but 16 of the successful pollinations were secured only when the hormone treatment was used. There were 22 in which seed was obtained from both treated and untreated flowers, but in all instances there was more seed in the untreated fruits. The averages were 56.7 seed per treated fruit and 104.5 per untreated fruit. The nine remaining successful crosses set about the same number of seed in both treated and untreated fruits. We do not know whether all the seed represents true hybrids since most of the plants thus far obtained will not flower for from one to several more years. We do know, however, that in some pollinations fruits and seed were obtained only when the hormone treatment was used. These particular crosses were: *amabile* x *pumilum*, *auratum* x *speciosum*, *auratum* x

FIG. 1. (A) Fruits on x *Lilium Brocade.* (1) Two selfs without hormone treatment. Note pistils failed to set fruit and also to assume an upright position. (2) Self-pollination with 0.1 per cent naphthalene acetamide; this fruit contained seed, and all untreated selfs of Brocade failed to form fruit. (3) Three fruits from cross Brocade x Mrs. R. O. Backhouse. All three were hormone treated.





(B) Fruits on self-incompatible Creole variety of *Lilium longiflorum.* Left, treated with 0.1 per cent naphthalene acetamide; right, untreated. Note persistence of style and swelling of stem below receptacle, both self-pollinated.

myriophyllum, auratum x *Henryi, Browni colchesteri* x *auratum, Davidi x tsingtauense,* Mrs. R. O. Backhouse x *Hansoni,* T. A. Havemeyer x *myriophyllum, Henryi* (upright variety) x T. A. Havemeyer, *(candidum* x *candidum* var. *Salonikae)* x *Testaceum, (Maxwill* x *Davidi)* x *Coronation, Brocade* x self, *Henryi (upright var.)* x self, *candidum* x self, *amabile* x self and *(dauricum* var. *Wallacei* x *dauricum* var. *venustum* f. *Batemanniae)* x *Maximowiczi.*

The pollinations that failed both with and without hormone treatments were: *tsingtauense* x *concolor, tsingtauense* x *Hansoni,* Brenda Watts x self, Brenda Watts x *Hansoni,* Brenda Watts x *pumilum,* Brenda Watts x *Parryi,* Brenda Watts x *concolor, Davidi* x *amabile,* Davidi x Coronation, *Parryi* hybrid x self, *Parryi* hybrid x *amabile,* Maxwill x *Duchartrei,* Mrs. R. O. Backhouse x self, *speciosum* (clone 81) x self, T. A. Havemeyer x self, *Testaceum* x self, *Hansoni* x self, *Hansoni* x Brocade, *Hansoni* x Dereham, *Hansoni* x Marhan, *Hansoni* x *tsingtauense, Hansoni* x *amabile; Henryi* x *auratum, Henryi* x *cathayanum, Henryi* x *Maximowiczi, Henryi* x *Sargentiae, Henryi* x Seneca, *Henryi* x *myriophyllum, Henryi* x *tigrinum, Henryi* x *(Wallacei* x *Batemanniae); Henryi* (upright var.) x self, *Marhan* x self.

The following pollinations yielded seed from both treated and untreated flowers, but more from the untreated: *tsingtauense* x self, *auratum* x self, *(auratum* x *speciosum)* x *auratum, (auratum* x *speciosum)* x self; Brenda Watts x *elegans,* Brocade x *Hansoni,* Brocade x Mrs. R. O. Backhouse, Brocade x Townhill; *Browni colchesteri* x *Browni, Browni colchesteri* x *myriophyllum; (candidum* x *Salonikae)* x self, *(Maxwill x Davidi)* x elegans, Mrs. R. O. Backhouse x Brocade, Mrs. R. O. Backhouse x Dereham; *speciosum* x *auratum, speciosum* x *Henryi, speciosum* x *(speciosum* x *auratum); Testaceum* x *candidum,* Marhan x *Hansoni, Testaceum* x *candidum* var. *Salonikae, Henryi* (var. upright) x *Henryi* (var. *citrinum*).

No difference was found in seed yield from treated and check pollinations in the following crosses: *tsingtauense* x Brocade, Brenda Watts x Coronation, Brenda Watts x *amabile; Browni colchesteri* x self, *candidum* x *candidum* var. *purpureum striatum, (candidum* x *Salonikae)* x *Salonikae, Davidi* x *elegans, myriophyllum* x T. A. Havemeyer, (T. A. Havemeyer x *Henryi*) x self.

In the pollinations that failed to set seed the hormone-treated flowers formed fruits in 41 per cent of the crosses and the checks in 12 per cent. Evidently some combinations are exceedingly incompatible, even though a fruit is formed. The effectiveness of the hormone treatment is not so pronounced on the species and variety crosses as on the self-pollinations of the *longiflorum* clones. The results secured, however, are promising, and further work is needed on testing the efficacy of other hormones as well as a wider range of concentrations.

Effect of Hormone, Pollen, and Hormone + Pollen on Fruit Formation:—Practically all lily ovaries will develop some sort of fruit when treated with 1 per cent concentration of naphthalene acetamide. An experiment was set up with the *longiflorum* clone Creole to determine what effect on fruit formation resulted from using (a) self-pollination, (b) hormone alone, and (c) hormone + self-pollination.

In the hormone treatment the styles were pinched off in order to prevent any possible pollination. Flowers of comparable age were selected and approximately equal numbers were given the above treatments. Collections of untreated and unpollinated ovaries were made when the experiment started, and treated and pollinated ovaries were collected at intervals of 2, 4, 6, 8, 10, 14, 16, and 20 days. The data are shown in Table I. It may be seen that the pollen + hormone treatment induces the greatest fruit development, but that considerable stimulation resulted from the hormone alone. When pollen only was used there was a slight growth stimulation during the first 16 days, but a sharp drop at 20 days.

TABLE I—GROWTH (WEIGHT) OF CREOLE LILY FRUITS FOLLOWING SELF-POLLINATION (P), TREATMENT WITH 1-PER CENT CONCENTRATION OF NAPHTHALENE ACETAMIDE (H), OR BOTH (H + P)

Treatment	No. Fruits	No. Days After Treatment	Weight Per Fruit (Mg)
O	25	0	466
O	25	0	459
P	20	2	461
H	18	2	554
H + P	18	2	560
P	15	4	469
H	16	4	705
H + P	16	4	616
P	14	6	551
H	14	6	789
H + P	15	6	819
P	9	8	579
H	12	8	993
H + P	12	8	1,024
P	18	10	599
H	26	10	1,188
H + P	22	10	1,148
P	13	14	605
H	14	14	1,491
H + P	17	14	1,586
P	14	16	655
H	15	16	1,961
H + P	14	16	2,153
P	13	20	484
H	19	20	1,697
H + P	16	20	2,004

In a later experiment of the same type with the Croft clone, direct reducing sugars and sucrose contained in the fruits were also determined. The samples were preserved in hot alcohol and extracted in soxhlets. The reducing power of the extracts was determined before and after treatment with invertase as previously described (11). The results are shown in Table II. The pollen alone treatment showed some stimulation for the first 6 days after which the ovaries lost weight rapidly. Total sugars increased for the first 12 days in all treatments, then dropped rapidly where pollen alone had been used. In the hormone and hormone + pollen treatments there was a steady increase in sugars per fruit up to 24 days after treatments were applied. When

TABLE II—GROWTH (WEIGHT) AND SUGAR CONTENT OF CROFT LILY FRUITS ANALYZED AT INTERVALS AFTER SELF-POLLINATION (P), TREATMENT WITH 1-PER CENT CONCENTRATION OF NAPHTHALENE ACETAMIDE (H), OR BOTH (H + P)

Treatment	No. Fruits	No. Days After Treatment	Weight Per Fruit (Mg)	Direct Reducing Sugars		Sucrose		Total Sugars	
				Per Cent Fresh Weight	Mg Per Fruit	Per Cent Fresh Weight	Mg Per Fruit	Per Cent Fresh Weight	Mg Per Fruit
None	19	0	616	0.30	1.85	0.20	1.23	0.53	3.26
P	12	6	808	0.27	2.18	0.51	4.12	0.80	6.46
H	12	6	983	0.21	2.06	0.50	4.92	0.74	7.27
H+P	13	6	1,115	0.10	1.11	0.56	6.24	0.68	7.58
P	11	9	691	0.66	4.56	0.60	4.15	1.30	8.98
H	11	9	950	0.43	4.08	0.43	4.08	0.88	8.36
H+P	10	9	1,490	0.16	2.38	0.39	5.81	0.56	8.34
P	10	12	650	0.92	5.98	0.69	4.48	1.66	10.79
H	10	12	1,130	0.54	6.10	0.30	3.39	0.87	9.83
H+P	10	12	2,450	0.27	6.61	0.34	8.33	0.63	15.43
P	10	16	280	0.45	1.26	0.14	0.39	0.61	1.71
H	10	16	2,165	0.44	9.53	0.57	12.34	1.03	22.30
H+P	10	16	3,280	0.53	17.38	0.47	15.42	1.02	33.46
P	10	20	170	0.31	0.53	0.29	0.49	0.63	1.05
H	10	20	5,240	0.47	24.63	0.36	18.86	0.85	44.54
H+P	10	20	5,900	0.53	31.27	0.36	21.24	0.91	53.69
P	10	24	60	Too small to analyze					
H	10	24	4,850	0.69	33.46	0.33	16.00	1.05	50.92
H+P	10	24	7,000	0.83	58.10	0.21	14.70	1.07	74.90

the hormone alone was used there was a high sugar content in the young developing fruits, but when pollen was also applied the total sugars increased further. During the first 16 days after treatment with naphthalene acetamide, sucrose accumulated in the ovaries in amounts nearly as great as or greater than the amounts of reducing sugars. This trend was reversed in the samples collected 20 and 24 days after treatment. On the latter date there was from two to three times as much reducing sugars as sucrose in the fruits. A similar experiment with the Ace clone yielded very comparable results.

The hormone treatment is capable of rapidly mobilizing carbohydrates in the young developing fruit. This may be a factor in the greatly delayed abscission of the style on treated lily ovaries. It may also delay degeneration of the embryo sacs and keep the egg cells viable for a longer period. This would afford more time for the pollen tubes to grow down the style.

The mobilization of sugars as a result of hormone treatment of kidney bean seedlings was reported by Stuart (10). The treatment brought about a directional shift of large amounts of nitrogen and carbohydrates from the leaves and cotyledons to other portions of the cuttings, principally to the treated hypocotyls. In the treated lilies there is always a noticeable swelling of the flower pedicel just where the ovary is attached. In the experiment with Creoles the upper three centimeters of the pedicel increased 47 per cent in weight in the 20 days following treatment with naphthalene acetamide. This condition persists until the fruit dehisces.

Summary

The results presented in this paper indicate that hormone treatment of lily ovaries at time of pollinations makes possible the securing of some difficult crosses and overcomes some self-incompatibilities. It is also shown that the treatment delays abscission of the style, increases sugars in the young developing fruit, and stimulates its growth. The action of pollen + hormone is shown to be greater than either one alone, but is not completely additive in effect.

It is also shown that both the pollen and hormone contribute directly to fruit formation in lilies. Perhaps the pollen action itself is hormonal. It is possible that some self-incompatibilities are primarily caused by the lack of sufficient hormonal activity at the time of pollination to set in motion the physiological activities necessary for fruit formation. Such types of incompatibilities caused by the pollen tubes reaching the ovules after they have degenerated, may also be overcome by hormones. It is not expected that all or even a high percentage of sterilities in plants can be eliminated in this way. There are undoubtedly many sterilities caused by other factors, many of which cannot be modified in any known way.

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Day Length and Flower Bud Development in Chrysanthemums

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THE daily light period was found sufficiently short for chrysanthemums to initiate flower buds at Ithaca (latitude 42 degrees N) after August 15 to 25 (1). Later work (unpublished) has shown that buds are not initiated on some late varieties in some years until September 3. This paper gives the results of treatments made to determine the date in September when the photoperiod is of favorable duration for flower bud formation and development of chrysanthemums.

The early variety, Arcadia (listed flowering time October 28) and the late variety, Goldsmith (listed flowering time November 25) were used in this work. Reactions of these varieties to daylength represent reactions of varieties normally flowering on similar dates. Cuttings were rooted in vermiculite. Twenty days after they were placed in the vermiculite they were transplanted to soil in the bench for flowering.

Twenty days after planting in soil the plants were pinched leaving all the leaves which were one-third expanded. Short days were given (30 days after pinching) by enclosing and covering the plants with black cloth at 4:30 pm and removing the cloth at 8:00 am the following morning. Lots were propagated May 20 and 30 and June 10 and 20. Plants were in different stages of bud development during September. Plants not receiving artificial short days before September 1 were exposed to 4 hours of light, minimum of 8 foot candles, each night from August 15 to September 1.

The data show Arcadia flowered earlier if given artificial short days to September 10, than when given normal days after September 1. The first flower was cut October 6 and the period of cutting was 10 days when normal day length was given September 1. The period of cutting extended 1 to 3 days when artificial short days were continued to September 10 and later.

Arcadia which was given short days August 20 to September 20, flowered 7 and 11 days earlier than similar plants under reduced daylength to September 10 and September 1 respectively.

The buds appeared simultaneously in all treatments, but days were evidently too long for rapid bud development before September 20. Buds were showing at the same time on plants under normal days as on plants given short days starting September 1. The flowering time was the same if given no short days. This shows that days are short enough at 42 degrees N latitude for buds to initiate September 1, but the days are not short enough for the most rapid development of flower buds.

Goldsmith was affected much like Arcadia. The buds apparently had not formed by September 1 or the initial stages of bud development were faster when short days were started September 1 than normal. Flower bud development was more rapid when short days were continued to September 20, than when normal days were given before September 20 if short days were started August 20. Short days started August 1, and September 1 caused Goldsmith to flower as

TABLE I—DAY LENGTH IN SEPTEMBER AND BUD FORMATION AND FLOWERING TIME*

Cuttings	Cultural Treatment				Arcadia				Goldsmith			
	Benched	Pinched	Black Cloth Started	Black Cloth Stopped	Date Buds Show	Date Color Shows	Date First Cut	Period of Cutting Days	Date Buds Show	Date Color Shows	Date First Cut	Period of Cutting Days
May 20	Jun 10	Jul 1	Aug 1	Sep 1	Aug 19	Sep 13	Oct 6	10	Aug 23	Sep 24	Oct 20	20
				Sep 10	Aug 18	Sep 14	Oct 6	3	Aug 23	Sep 23	Oct 15	9
				Sep 20	Aug 18	Sep 14	Oct 6	3	Aug 21	Sep 22	Oct 10	10
				Sep 30	Aug 19	Sep 13	Oct 6	1	Aug 22	Sep 22	Oct 15	3
May 30	Jun 20	Jul 10	Aug 10	Sep 1	Aug 26	Sep 27	Oct 17	8	Sep 4	Oct 18	Nov 5	6
				Sep 10	Aug 26	Sep 24	Oct 10	6	Sep 1	Oct 4	Oct 24	11
				Sep 20	Aug 26	Sep 24	Oct 10	6	Sep 1	Oct 3	Sep 24	1
				Sep 30	Aug 26	Sep 24	Oct 10	6	Sep 4	Oct 4	Oct 24	4
Jun 10	Jun 30	Jul 20	Aug 20	Sep 1	Sep 5	Oct 8	Oct 28	1	Sep 13	Oct 8	Nov 14	1
				Sep 10	Sep 7	Oct 6	Oct 24	6	Sep 10	Oct 9	Nov 3	1
				Sep 20	Sep 6	Oct 3	Oct 17	8	Sep 10	Oct 8	Oct 27	8
				Sep 30	Sep 5	Sep 29	Oct 17	8	Sep 11	Oct 6	Oct 27	8
Jun 20	Jul 10	Jul 30			Sep 18	Oct 17	Oct 29	5	Oct 3	Oct 30	Nov 17	1
			Sep 1	Sep 10	Sep 20	Oct 16	Nov 3	1	Sep 24	Oct 23	Nov 7	8
				Sep 20	Sep 20	Oct 15	Nov 3	1	Sep 22	Oct 20	Nov 7	8
				Sep 30	Sep 21	Oct 14	Oct 29	5	Sep 22	Oct 18	Nov 5	10

*Mr. F. F. Horton, foreman at the Cornell greenhouses and his assistants cared for the plants and collected the data.

quickly if given normal day length after September 10 as when short days were continued later.

From these data it is evident that the days were short enough for bud formation on Arcadia by September 1 and on Goldsmith within a few days after September 1, but days were not short enough for the most rapid bud development of certain sized buds until September 20.

The length of day including civil twilight was recorded (2), and is presented in Fig. 1. It is evident that 2 years would not produce equal results, and continued treatment after September 1 might not always hasten flower bud development. The year 1947 was ideal for this project because the days were nearly the maximum possible length to September 15.

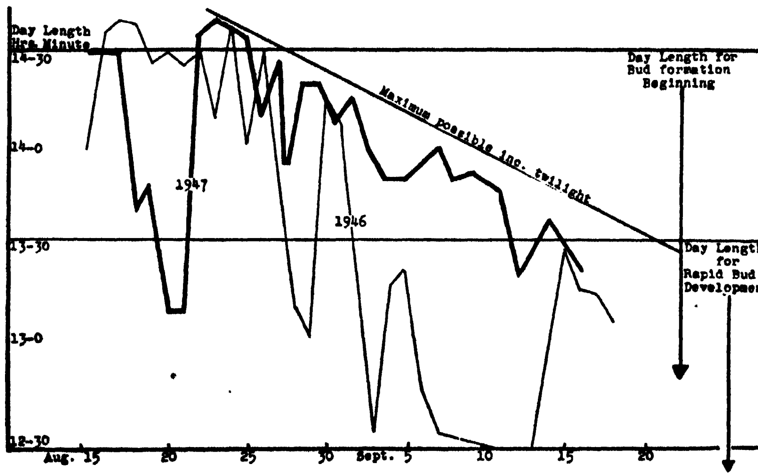

FIG. 1. Day length 1947 compared with 1946 and maximum possible. Flower buds start to form when the days are 14 to 14½ hours long. Within this range of day length buds do not develop to flowering. When the days are less than 13½ hours long buds develop normally. Buds appear to develop most rapid when the days are less than 13 hours long.

From these data and other accumulated previously it is evident that flower buds of chrysanthemums initiate when the daily light period is 14 to 14.5 hours, but most rapid flower bud development does not occur until the light period is 13 to 13.5 hours. More accurate determination of this is necessary before establishing the critical day lengths for both reactions.

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Growing Chrysanthemums in Subirrigated Vermiculite for Spring Bloom

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STUDIES conducted at the Plant Industry Station, Beltsville, Maryland, since 1940 have shown that the normal blooming season of a single planting of greenhouse chrysanthemums can be extended for three or more months by the use of short periods of light applied at the middle of the night (3). Such a practice is of value in extending into the winter the season of varieties normally flowering in November and December. For later bloom in the winter or spring it would be more economical to bench the plants in the fall or winter, provided good growth could be obtained at that season. Post (2) has reported flowering chrysanthemums throughout the year at Cornell University. Gifford (1) has described the production of a spring crop of chrysanthemums in 1946 at Ohio State University. These studies indicate that with proper attention to cultural methods it is possible to flower chrysanthemums at will. One of the important problems needing further study is the evaluation of existing varieties for out of season production. It is also of importance to determine the optimal supplemental light treatment for vegetative growth and prevention of flowering as well as conditions necessary for flower production. The purpose of the present study is to record the performance of 15 varieties of chrysanthemums grown in vermiculite for spring bloom.

Rooted chrysanthemum cuttings supplied through the courtesy of Yoder Brothers, Barberton, Ohio, were planted in expanded vermiculite of the S. F. Terra-Lite grade on January 22, 1947, following a fall crop of November-flowering varieties which had been flowered in early January. Fourteen cuttings of each variety were spaced 6½ by 8 inches in each of eight concrete greenhouse benches which were subirrigated twice weekly, with a nutrient solution of the following composition, as parts per million: nitrogen, 14 from ammonium sulfate and 56 from sodium nitrate; phosphorus, 31 from super-phosphate; potassium, 97 from potassium chloride and potassium sulfate, one-half from each; magnesium, 24 from magnesium sulfate; iron, 2 from ferrous sulfate; zinc, 0.15 from zinc sulfate; manganese, 0.75 from manganese chloride; boron, 0.5 from boric acid; copper, 0.06 from copper sulfate.

Commencing January 26th each bench was lighted by 60 or 100-watt bulbs in 12-inch reflectors spaced 4 feet apart and 3 feet above the 57-inch-wide benches. Minimum light intensity from the 60-watt bulbs was 10 foot-candles; and from the 100-watt bulbs, 16 foot-candles at the sides of the bench. The light treatments were applied nightly, two benches receiving each treatment, as follows:

1. 36 minutes commencing at 1:00 a m, from 100-watt bulbs.
2. 3 hours commencing at 11:00 p m, from 60-watt bulbs.
3. 3 hours commencing at sunset, from 60-watt bulbs.
4. 1 hour commencing at 1:00 a m, from 60-watt bulbs.

Four bunches were maintained at a night temperature of 58 to 60

degrees F, and four at 53 to 55 degrees F. All plants were soft pinched when 6 to 7 inches tall, 15 to 20 days after setting the cuttings, and pruned to three stems. The standard, Yellow Orchid Queen, was grown to a single stem.

The lights were discontinued in the greenhouse maintained at 58 to 60 degrees on March 26th, when the plants ranged from 15 to 20 inches in height. Buds were visible on plants of Arcadia, Barcarole, Constellation, Mary McArthur, Pristine, Shasta, and Yellow Orchid Queen in the 36-minute and 1-hour treatments. Buds were forming on the varieties Constellation and Pristine that had been lighted for 3 hours at sunset, but none were apparent on any of the plants lighted from 11:00 p m to 2:00 a m. As soon as use of the lights was stopped the plants were shaded nightly from 4:30 p m to 6:30 a m with new black sateen. Shading was continued nightly until the flowers were cut. Data showing averages for 14 plants for blooming date, number of flowers per plant, average plant height, and number of 13-ounce bunches of flowers cut 31 inches long are given in Table I for each

TABLE I—Blooming Date, Number of Flowers per Plant, Average Plant Height, and Number of 13-Ounce Bunches of Flowers per 14 Plants for Each of 15 Chrysanthemum Varieties Grown With Each of Four Supplemental Light Treatments

Variety	Average Blooming Date				Average No. Flowers Per Plant				Average Plant Height (Inches)	Average No. 13-Ounce Bunches of Flowers Per 14 Plants§
	Light Treatment				Light Treatment					
	I*	II**	III***	IV†	I*	II**	III***	IV†		
Arcadia	May 19‡	Jun 7	May 31	Jun 3‡	39	25	36	34	37	4.0
Barcarole	May 26‡	Jun 6	Jun 6	May 30‡	47	28	33	42	40	5.4
Constellation	May 10‡	Jun 5	Jun 2‡	¶	18	25	25	—	26	3.5
Gold Coast	May 27	May 31	Jun 6	May 30	29	30	22	27	33	3.2
Golden Herald	May 19	Jun 5	Jun 5	Jun 3	26	26	26	28	48	5.3
Melody	May 27	Jun 3	Jun 5	May 28	30	24	16	24	44	5.2
Mary McArthur	May 16‡	Jun 1	Jun 1	May 23‡	12	15	18	16	35	3.1
Pinocchio	May 26	May 31	¶	May 26	54	53	—	52	38	3.9
Pristine	May 16‡	Jun 9	Jun 9‡	May 20‡	17	10	12	13	32	2.0
Shasta	May 26‡	Jun 9	Jun 9	Jun 5‡	20	16	15	18	41	3.1
Soprano	May 21	May 30	Jun 5	May 26	25	23	21	27	42	3.1
White Mensa	May 26	Jun 1	Jun 9	May 30	24	22	12	21	43	5.0
Yellow Lakme	May 30	Jun 5	Jun 6	Jun 5	33	26	25	34	44	3.9
Yellow Sea Gull	Jun 9	Jun 9	Jun 9	Jun 9	19	24	21	17	48	4.8
Yellow Orchid Queen	May 28‡	Jun 2	Jun 9	Jun 1‡	Single stem				33	—
Average	May 24	Jun 4	Jun 6	May 30	28	25	22	27	39	4.0

*36 minutes of light nightly, commencing at 1 a m from 100-watt bulbs.
**3 hours of light nightly, commencing at 11 p m, from 60-watt bulbs.
***3 hours of light nightly, commencing at sunset, from 60-watt bulbs.
†1 hour of light nightly, commencing at 1 a m, from 60-watt bulbs.
‡Buds visible March 26, when lights were discontinued and shading was started.
§Bunches 31 inches long.
¶Not variety listed.

variety and light treatment. These data show, as would be expected, that the plants on which buds formed before shading was started bloomed from 1 to 3 weeks earlier than plants of the same varieties subjected to the longer daily light treatment. This earlier blooming did not reduce the number of flowers per plant except in the variety Mary McArthur. In fact the average number of flowers per plant for

all of the varieties tested was slightly higher from the 36-minute and 1-hour treatments than from either of the 3-hour treatments.

The average production amounted to four 13-ounce bunches of flowers cut to 31 inches in length per 14 plants grown in approximately 5 square feet of bench space. Flower quality was excellent and equal to that produced in November or December, except that Melody and Soprano were somewhat bleached in color, although otherwise acceptable. Blooms on Yellow Orchid Queen averaged 4½ inches in diameter and were of excellent quality. It is noteworthy that terminal rather than crown buds were formed in all treatments.

Lights were discontinued on April 4 in the greenhouse maintained at 53 to 55 degrees F. Buds were visible on the same varieties in the short light treatments as in the house held at 58 to 60 degrees. No buds were visible on the plants lighted from 11:00 p m to 2:00 a m. The average blooming dates were: 36-minute treatment, June 10; 1-hour, June 12; 3-hour starting at sunset, June 13; and 3 hour starting at 11:00 p m, June 16. Production averaged 3.8 bunches per 14 plants. Data for Melody and Yellow Sea Gull were not included, since these varieties bloomed slowly and unevenly. Chrysanthemum varieties normally blooming late in the fall are not well adapted for spring bloom since they tend to remain vegetative. Pink varieties produce lighter-colored blooms while bronze varieties may appear yellow. Conversely, early in the spring some white blooms may be slightly cream colored. Of the varieties used in the present test White Mensa, Arcadia, Pinocchio, Barcarole, Gold Coast, and Golden Herald were the most satisfactory.

The question of optimal light treatment at various seasons of the year is still not definitely determined. Excessively long periods of supplemental illumination may be undesirable, not only because of cost but also because the number of flowers per plant may be reduced. Short periods of high intensity light may be more effective than longer periods of lower intensity, although the latter will probably be used. Regardless of the light treatment more time will be required for producing a crop of chrysanthemums in the winter than in the spring or fall.

In the present study expanded vermiculite proved a very satisfactory soilless culture medium. No plants were lost and the high capacity of the vermiculite for holding moisture and nutrient was well adapted for rapid plant growth.

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Automatic Watering of Potted Plants[1]

By John G. Seeley, *Cornell University, Ithaca, New York*

The usual surface method of watering potted plants is a time-consuming operation that adds greatly to the cost of production. Automatic methods of watering potted plants have been devised to reduce the amount of labor required. These methods are of value not only to the commercial grower but also to the scientific investigator who is thus able to grow plants with excellent soil moisture conditions and a minimum requirement of time and labor for watering.

Injection

Post (2) and Post and Seeley (4) described a subirrigation method in which potted plants are placed on gravel in a water-tight bench and water is injected until the lower one-third to one-half of the pot is submerged. When the surface of the soil becomes moist, the excess water is drained to a tank for re-pumping or drained to a sewer. All types of potted plants in all sizes of pots have been grown successfully by this method.

Constant Water Level

To further simplify the watering of potted plants, the constant water-level method was developed (6), making use of the principle of capillary movement of water in all directions in the pores of the soil, sand and pots.

Reid, Cowgill and Close (5) in their study of the plunging of potted tomato, cabbage, salvia, and several other types of plants in relation to moisture and nutrient supply found that plunging the pots in sand or peat and watering the plunging material "reduces to a small fraction the time necessary for watering, favors uniformity of supply to all pots in accordance with their individual needs and withal produces better plants". By means of a constant water level the plunging medium can be watered automatically thus reducing the labor requirement still further.

This method in general consists of placing the potted plants on a layer of sand or plunging the pots in sand in a water tight bench with a constant water level 1 inch below the pot (Fig. 1). Water moves from the water table in the bottom of the bench through the sand, through the walls of the pot and through the soil in the pot. As water is removed from the soil by plants and by evaporation, more water moves into the soil by capillarity.

The amount of water required by the plant and the rate of supply to the plant by capillarity depend on (a) size of plant, (b) time of year, (c) type of soil, (d) type of pot, (e) type of sand under the pot, (f) size of pot, and (g) depth of plunging. Large plants require more water than small plants, and the water requirement is greater in summer than in winter. Different soils, sands, and pots vary in their

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[1]Appreciation is expressed to Fred Horton, superintendent of the greenhouses, and his assistants for their help in conducting these experiments.

ability to transmit water by capillarity. Soils increase in dryness in proportion to the distance from the water table; the upper surface of the soil in a 6-inch pot would therefore tend to be drier than the surface soil of a 2¼-inch pot if both were placed with the bottom of the pot at the same height above the water table. The depth of plunging of the pot in the sand is important because a pot plunged in sand will have less pot surface exposed for evaporation and more area through which water can move from the sand to the soil than a pot setting on the surface of the sand. The ease of moisture movement through pot walls has been demonstrated by several investigators (1, 5).

In order to study the effect of some of these factors in relation to the constant water level method of growing potted plants, many types of plants in various sized pots were grown with various depths of plunging with the water table at several distances below the pot.

In all experiments the V of the water tight bench was filled with pea gravel as shown in Fig. 1 and various depths of ordinary bank sand placed on the gravel. The water table was maintained constantly at the junction of the gravel and sand by means of a poultry float valve. The plants after being set in the bench were thoroughly surface watered to establish capillarity and then subsequently automatically watered from below. The soil was a Genesee silt loam which had been composted with 25 per cent manure. Subsequent fertilization was by means of liquid fertilizers applied to the soil surface.

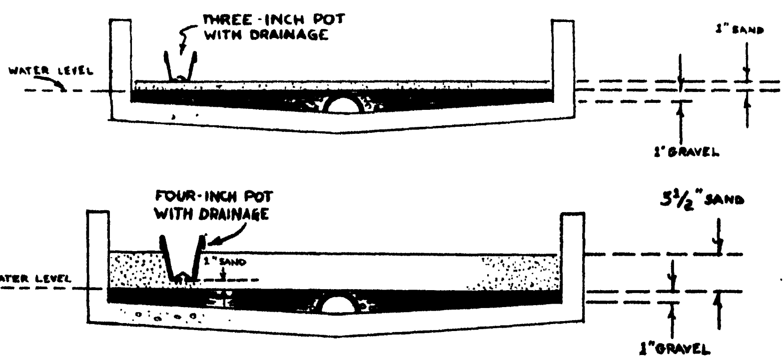

FIG. 1. Benches with pots on sand and plunged in sand for automatic watering by the constant water level method.

Experiment 1:—Rooted geranium cuttings, variety Mme. Landry, were potted in 4-inch pots on April 2, 1946 and grown at 60 degrees F night temperature. Twenty-four plants were surface watered daily and a like number were injection watered. Twenty-four plants were plunged in sand up to the rim of the pot and a constant water level maintained 1 inch below the base of the pot. Fifty per cent of the plants were in flower as in Fig. 2, 6 weeks later on May 15, and 90 per cent were in flower on June 2. The top growth of the surface watered plants was a little more compact than of those which were automatically watered. Root development was good with all three methods.

FIG. 2. Geranium plants watered by each method, photographed six weeks after potting. Left — surface; center — injection; right — constant water level, plunged to rim with water one inch below pot.

Experiment 2:—Rooted cuttings of Mme. Landry geraniums were potted in 4-inch pots on November 14. Plants were grown with surface watering and injection watering in addition to the constant water level. Pots were plunged to a depth of 1 inch, 2 inches, and up to the rim; for each depth of plunging, plants were grown with the water table 2 inches below the pot, 1 inch below the pot, and touching the base of the pot. Twelve geraniums were grown in each of these 11 treatments in night temperatures of 50 and 60 degrees.

All the plants grown in the 60 degrees F house were in full flower or with buds showing color by January 20 (9 weeks after potting). Those in the 50 degrees F house were in similar condition by February 12 (13 weeks after potting). Representative plants of five treatments with 60 degrees F night temperature are shown in Fig 3; there was no difference in size of the plants or time of flowering as the result of the different watering treatments.

The effect of moisture on root development is demonstrated in Fig. 3. The center plant was plunged 1 inch in the sand and the roots were concentrated in the lower inch of the root ball. The fourth plant from the left was plunged 2 inches and the roots were more abundant in the

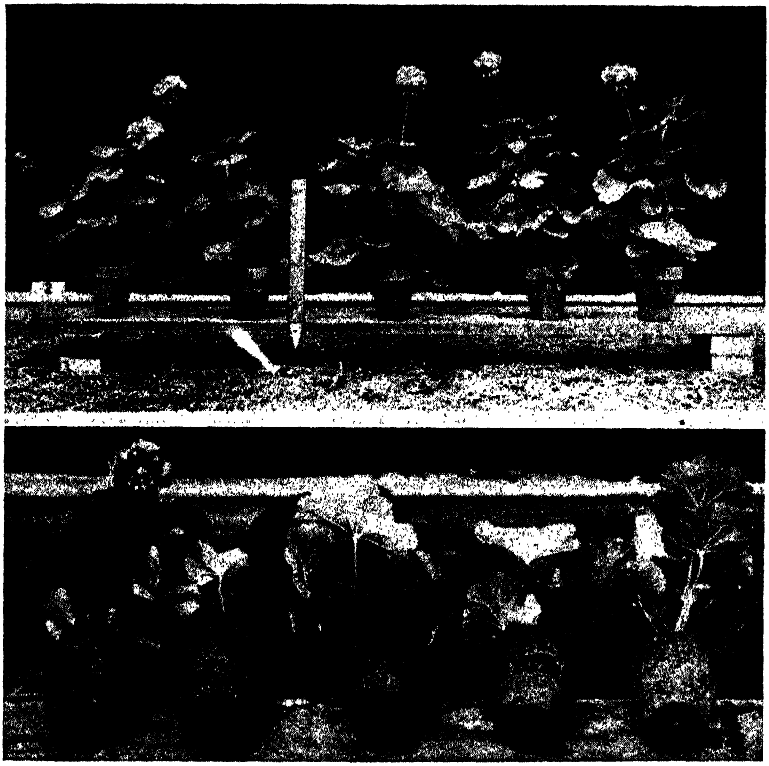

FIG. 3. Effect of watering on tops and roots of geraniums grown at 60 degrees F. Left to right; surface-watered; injection watered, constant level (three to right): plunged 1 inch, plunged 2 inches; plunged to rim; water table 1 inch below all pots.

lower 2 inches of the soil ball. The plant on the right was plunged to the rim of the pot and the roots, which were well distributed throughout the soil, were as well or better developed than roots of the surface watered plants. Plants grown with water touching the pot were chlorotic and the roots were injured because of anaerobic conditions in the soil.

To compare the root development of fully plunged plants grown by constant water level with those grown by surface watering and injection, the root systems of six plants from each treatment were carefully washed and dried at 115 degrees C for 18 hours; the tops also were dried and weighed. There was little difference in the weight of the root systems, those of the surface watered plants weighing 3.20 ± 0.17 grams (standard error of the mean), injection watered plants 3.80 ± 0.36, and constant water level, plunged to rim with water 1 inch below the pot, 3.73 ± 0.74. The tops of the plants weighed 12.00 ± 0.44, 10.60 ± 0.71, and 12.90 ± 0.19 respectively.

Experiment 3:—Rooted geranium cuttings of the variety Mme. Landry were potted in 4-inch pots on March 14, 1947 and grown at 60 degrees F night temperature. Plants were surface watered, injection watered and automatically watered with a constant water level 1 inch below the pots. Pots were plunged ¼ inch, 2 inches and to the rim in sand. The plants in all treatments grew well with no difference in size of plant or flowering with the different watering methods. By May 16, 9 weeks after potting, 90 per cent of the plants were in flower and in good salable condition.

The plants in pots plunged to the rim with the water table 1 inch below were given one surface watering on May 4. Of the plants in pots plunged ¼ inch with the water table 1 inch below, a few required watering each week. These plants had a ¼ inch layer of medium fine cinders in the bottom of the pot to facilitate drainage when the plants were surface watered after sale. Subsequent experiments showed that by using no drainage material except a piece of broken flower pot ("crock") over the drainage hole, there was better contact of the soil with the bottom of the pot, thus improving movement of moisture into the soil, and plants were adequately watered automatically when the pots were pressed ¼ inch into the sand.

Experiment 4:—Rooted poinsettia cuttings of the variety Mrs. Paul Ecke were potted in 2¼-inch pots on September 17 and watered by the methods given in Table I. After the initial surface watering when

TABLE I—CONDITION OF POINSETTIA ROOT SYSTEMS (OCTOBER 7, 1946)

Watering Method	Number of Plants		
	Good	Fair	Poor
Surface	11	1	0
Injection	11	1	0
Plunged to rim; water 1 inch below pot	12	0	0
Setting on sand; water 1 inch below pot	12	0	0
Plunged to rim; water ½ inch below pot	8	1	3
Plunged 1 inch; water ½ inch below pot	8	2	2

the plants were set in the bench, the automatically watered plants required no further surface watering. The root systems were examined and graded October 7. All of the watering treatments were good except when the water was only ½ inch below the pot (Table I); the excess moisture in the soil of these pots inhibited root growth because of inadequate oxygen supply. The plants with good and fair root systems were panned in 6-inch pots on October 8 and all were then automatically watered by plunging the pots to the rim with a constant water table 1 inch below the pot. None of these plants required surface watering. The plants had large bracts and no loss of the lower foliage, and all were in good salable condition for Christmas.

Another lot of rooted cuttings planted in 2¼-inch pots on November 2 was watered by the methods given in Table II, and the root systems were graded on December 8. Both root development and top growth with all of the watering treatments were good except when the water touched the bottom of the pot.

Experiment 5:—Rooted poinsettia cuttings, variety Mrs. Paul Ecke,

TABLE II—CONDITION OF POINSETTIA ROOT SYSTEMS (DECEMBER 8, 1946)

Watering Method	Number of Plants		
	Good	Fair	Poor
Surface	34	8	0
Injection	35	7	0
Plunged to rim; water 1 inch below pot	39	3	0
Half plunged; water 1 inch below pot	36	6	0
Setting on sand, water 1 inch below pot	35	7	0
Plunged to rim; water touching pot	30	3	9

were potted September 16 directly in 6-inch pans with three plants per pot and grown by surface watering, injection watering and the constant water level method. Plants were grown with pots plunged to the rim, plunged 2 inches, and setting on sand, all with the water table 1 inch below the pot. Some also were plunged 2 inches with the water table 2 inches below. Rooted cuttings also were potted October 18 and set up in a similar arrangement. Each treatment contained 12 pots. The plants were all grown at 58 to 60 degrees F night temperature.

The effect of size of plants on the water requirement was demonstrated. Surface and injection-watered plants were watered daily. Plants in pots plunged to the rim and those plunged 2 inches with the constant water table 1 inch below the pot were watered automatically until early December when the plants potted in September required surface watering once a week to re-establish capillarity. Plants of the October potting in these two treatments did not require surface watering. Apparently the larger plants of the earlier propagation had a greater water requirement than did the smaller plants of the second propagation, and under these conditions water did not move fast enough by capillarity to supply the large plants.

Plants of both propagations in pots half plunged with the water table 2 inches below or with the pots on the sand with the water table 1 inch below were not satisfactorily watered automatically and required occasional surface waterings during the last 3 weeks of growth.

The only difference in height of plants as a result of the watering treatments was that the plants setting on sand tended to be somewhat shorter than the other automatically watered plants and the surface watered plants. The size of bloom and quality of the plants were good with no difference between treatments. All were in excellent condition for Christmas and lasted equally well under home conditions.

Experiment 6:—Seed of Siter's and Cremer's strains of cineraria were sown September 24, 1946, potted in 2-inch pots on October 31 and later shifted to 6-inch pots. The watering treatments consisted of surface, injection and constant level. The latter were plunged ½ inch and plunged to the rim with the water 1 inch below the pot, and plunged to the rim with water touching the pot. The plants flowered in February and the quality with all watering methods was good, except for those plants with water touching the bottom of the pot. The roots in the lower half of the root ball of these plants were dead and the foliage was light yellowish green in color.

Experiment 7:—Rooted cuttings of begonia Lady Mac were potted in 3-inch pots on April 24, shifted to 4-inch pots on June 23, and finally into 5-inch pots on September 18th; the night temperature was maintained at 60 degrees F when possible. Because of lack of space, the plants were all surface watered until July 3; the plants were then surface watered by injection, and constant water level. With the latter method pots were plunged ¼ inch, one-half the depth of the pot, and to the rim. The water table was 1 and 2 inches below the pot for each treatment except those plunged ¼ inch where the water table was 1 inch below the pot. There were 24 plants in 4-inch pots in each treatment; when shifted to 5-inch pots and spaced farther apart, the number was reduced to 15 plants.

One-quarter inch of cinders was placed in the bottom of the pots in all treatments. In order to study the effect of drainage material on water movement 12 plants were potted with no drainage except a piece of crock over the drain hole and then pressed ¼ inch into the sand with a constant water table 1 inch below the pots.

When the surface soil of any pot appeared dry, the plant was inverted and tapped lightly out of the pot; if the soil ball was dry, the plant was surface watered. The dates and number of plants requiring surface watering are presented in Table III. The cinder drainage in the pots pressed ¼ inch into the sand interfered with water movement to the soil ball and many plants had to be surface watered. As soil gradually sifted down and roots penetrated the cinders, these plants no longer required surface watering. In the pots which were plunged one-half their depth or to the rim, the cinder drainage did not seriously interfere with the water supply because the water was able to move through the walls of the pot above the cinder layer. Only a few plants in these treatments required surface watering. Except for three plants on August 3, none of the plants with no drainage and plunged ¼ inch required surface watering.

The plants were surface watered to establish capillarity after they were shifted to 5-inch pots, and, with the exception of plants with drainage and plunged ¼ inch, no plants in any of the constant water level treatment received any further surface watering. The plants in

TABLE III—Begonia Plants Requiring Surface Watering in the Constant Water Level Treatments

Plunged ¼ Inch, Water 1 Inch Below Pot, Cinder Drainage		Plunged ¼ Inch, Water 1 Inch Below Pot, No Drainage		Plunged ½ Depth of Pot, Water 1 Inch Below		Plunged to Rim, Water 1 Inch Below		Plunged ½ Depth of Pot, Water 2 Inches Below		Plunged to Rim, Water 2 Inches Below	
Date	No. of Plants	Date	No. of Plants	Date	No. of Plants	Date	No. of Plants	Date	No. of Plants	Date	No. of Plants
Jul 22	7	Aug 3	3	Jul 22	6	Jul 22	3	Jul 22	5	Jul 22	4
Jul 29	8			Aug 4	12	Aug 6	6	Aug 6	7	Aug 6	7
Aug 1	12							Aug 15	3		
Aug 4	7										
Aug 6	4										
Aug 7	3										
Sep 22	4										
Sep 27	4										
Sep 30	3										

all of the treatments were in full flower and excellent salable condition on November 25 with no difference between treatments.

Roots were distributed depending on depth of plunging similar to those of the geraniums in Experiment 2. Root development was best when the pots were fully plunged but these differences in root growth were not reflected in the top growth.

Experiment 8:—Kalanchoe seed of the variety Tom Thumb were planted on February 21, and potted in 2-inch pots on April 3, and shifted to 3-inch pots on June 23. These plants were watered automatically by setting the pots on sand with a constant water table 1 inch below the pots. The plants were shifted to 4-inch pots on September 3 and given the same watering treatments as the begonias in Experiment 7, with 45 plants per treatment. They were grown at 60 degrees F minimum night temperature. Black cloth treatment to produce short days was given from September 16 to October 10. The plants in all teratments were in full flower on December 20 with no difference in quality and growth between treatments. None of the plants required surface watering except for a few of the pots with drainage and plunged ¼ inch. The root development of these plants was superior to the other treatments; plants plunged one-half the depth of the pot and those plunged to the rim with water 2 inches below the pots developed better roots than similar treatments with the water 1 inch below the pots. Apparently Kalanchoe roots grow better with less soil moisture than the other plants in these studies; it may be that Kalanchoe roots require a higher oxygen supply for growth.

Other plants that were watered and grown successfully by the automatic constant water level method are cyclamen, lilies, narcissi, Saintpaulias, azaleas, hydrangeas, and snapdragons.

The recommended procedure is to put the water conductor and gravel in the bottom of a level, water-tight bench and level the gravel in water. Put 1 inch of sand on the gravel. Use only a piece of "crock" or nothing over the drainage hole when potting the plants. Place the potted plants on the sand pressing the pots lightly into the sand to get good contact between sand and pot. Surface water the soil to establish capillarity. Establish a constant water level 1 inch below the bottom of the pot. If the plants do not obtain sufficient water automatically, add more sand and plunge the pots. If the soil remains too wet causing reduction of the oxygen supply, lower the water table. The water table should not contact the bottom of the pot. Because of the labor involved in plunging pots and spacing plunged pots, it is most economical to plunge the pots as little as possible and still have automatic watering.

Copper Tube Method

Because a water-tight bench is required for the constant water level and injection methods, an adaptation of the copper tube method described by Post and Scripture (3) was used. Plants were set on sand or plunged in sand in a non-water tight bench. Lining the bench with asphalt roofing paper helps to conserve moisture by decreasing the rate at which water will drain through the bottom of the bench. The sand was moistened (Fig. 4) by means of two lines of copper tube with

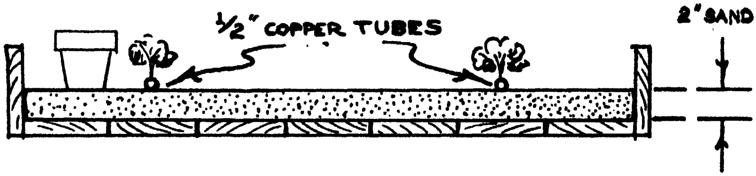

FIG. 4. A non-water-tight bench for the copper-tube watering of potted plants.

orifices 12 inches apart; the water was applied until the sand was thoroughly saturated. Geranium and poinsettia plants in 4-inch pots grew satisfactorily when the water was allowed to run once each day until drip started through the bottom of the bench. The frequency of application would be governed by such factors as the size of plant, time of year and depth of plunging and would have to be determined by the individual grower. The water could be turned on and off each day automatically by means of a time clock and solenoid valve as described for automatic watering of bench crops (4).

SUMMARY

Injection, constant water level, and copper tube automatic methods of watering of potted plants are described.

Plants watered by these three methods are equal in quality or better than those which were surface watered.

Uniform soil moisture conditions for the growth of potted plants can be maintained automatically with a minimum of labor by means of the constant water level method.

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The Growth of Stocks and China Asters on Four Iowa Soils With Constant-Level Sub-Irrigation[1]

By J. A. Stephens and E. C. Volz, *Iowa State College, Ames, Ia.*

Studies on the behaviour of greenhouse crops grown in sub-irrigated benches began as early as 1890 at the Ohio Agricultural Experiment Station (2). Various modifications of the Ohio method were tried by workers at the New York, West Virginia, Wisconsin, New Hampshire and Indiana Experiment Stations. These early attempts to improve methods of greenhouse watering met with little response and sub-irrigation was abandoned by greenhouse operators. Recently, Post and Seeley (6, 7) and others demonstrated that sub-irrigation, if properly used, played an important role in meeting the war period demand for labor-saving devices. Experiments with the "Constant-Level" method of sub-irrigation were begun at Cornell in 1945. Post and Seeley (7) had previously improved the technique of sub-irrigation as well as the use of tensiometers and reported superior growth response in greenhouse plants watered in this manner.

As yet, little work has been done to determine the fitness of various soil types when used in sub-irrigated benches. The purpose of the experiments to be described in this paper is to make a comparison of several Iowa soil types and their behaviour under constant level sub-irrigation.

Procedure

Four Iowa soil types, representative of the soil being used by growers in the most important greenhouse areas in the state, were selected for this study. Samples of these four soil types, along with others, had been used in experiments by Volz and Stenstrom (8) in the bench culture of snapdragons and stocks with surface watering. The following table gives the location and a brief description of the soils selected for the experiment.

TABLE I—Location and Type of Soils Selected for the Experiment

Location	Soil Type	Remarks
Charles City	Carrington silt loam	Upland prairie soil
Ames (College Farm)	Webster clay loam	Prairie soil
Davenport	Clinton silt loam	Forest soil weathered from loess, low in organic matter
Council Bluffs	Monona silt loam	Forest soil weathered from loess, high in organic matter

Two and one half cubic yards of each soil type were needed to permit six duplicate plots per soil type in the two concrete "V-bottom" benches measuring 57 feet 5 inches by 4 feet 4 inches. The bottom of the "V" was ⅞ inch lower than the sides. Since half-tile was unavailable, inverted wooden troughs were used to permit unobstructed flow of water in the bottoms of the partitioned benches. A layer of gravel,

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1 inch in depth at the sides, was placed in the bottom of the bench, and 1 inch of unscreened sand covered the gravel layer. Approximately 4½ inches of soil were then placed in the benches. The replicated soil types were separated by wooden partitions extending to the sand layer.

The intake of water in the bottom of the bench was controlled by float valves, of the type commonly used for poultry water tanks. After experimentation, the float valves were adjusted to maintain 1 inch of water in the bench when measured at the lowest part of the "V". It was found that this water level, entirely within the gravel layer, kept the soil moist in all parts of the bench.

Stocks, *Matthiola incana,* var. Lilac Lavender, were used as the early crop, and, for a summer "follow-up" crop, the China aster, *Callistephus chinensis,* vars. Royal dark lavender and Royal shell pink. In the experiment with the China aster one-half of each soil plot was planted to the varieties previously mentioned. The design of the experiment was randomized complete block, with four soils and six replications. There were 95 plants in each replication with a total of 2,304 plants employed in each of the two experiments. The stocks were cut at the soil surface when 10 florets had opened, and data on total height, length of inflorescence, and number of florets, plus buds were recorded. The China asters were disbudded to a single stem, and height of plant and diameter of flower recorded for each individual.

Soil Differences and Characteristics

Mechanical analysis, organic matter determinations, and pore space analyses were made to determine how the four soils differed in these respects. The data presented in Table II were obtained by the pipette method of Olmstead, Alexander, and Middleton (5).

TABLE II—Mechanical Analyses of Monona, Carrington, Webster, and Clinton Soils (in Percentages)

Soil	Sand 300 Mesh	Silt	Clay
Monona silt loam	4.4	76.5	19.1
Carrington silt loam	20.3	56.2	23.5
Webster clay loam	18.1	54.8	27.1
Clinton silt loam	3.8	82.1	14.1

The organic matter determinations were made by the chromic acid titration method (8). Monona silt loam had 6.6 per cent organic matter, Webster 6.1 per cent, Carrington 5.3 per cent and Clinton 2.0 per cent.

The pore space analyses, obtained by the method of Leamer and Shaw (4) showed slight differences in total porosities and capillary porosities as shown in Table III.

Since non-capillary pores or macropores, which lie between the larger soil grains and granules, allow ready movement of air and water, while capillary pores or micropores, which are usually clogged with water under the conditions of sub-irrigation, provide little aeration for plant roots, the macroporosity values obtained were con-

TABLE III—Porosity of Soils Used

Soil	Total Porosity	Capillary Porosity	Non-Capillary Porosity	Solids
Monona	68.9	44.3	24.6	31.1
Webster	63.9	43.9	20.0	36.1
Clinton	63.9	46.7	17.2	36.1
Carrington	63.3	38.9	24.4	36.7

sidered more significant than either total porosity or capillary porosity values.

Macropore volume is relatively large in sandy soils, and in those soils where a high organic matter content encourages the formation of crumbs and granules, as well as aggregates of mineral particles and humus. It will be noted that Monona silt loam with the highest percentage of organic matter has the highest percentage of non-capillary pore or macropore space. In contrast, Clinton silt loam, containing the least organic matter, has the lowest percentage of macropore space. Apparently none of the four soils used had a sufficient percentage of sand to provide an appreciable increase in macroporosity.

Fertility of Soils

It was decided to place emphasis on the physical and structural differences of the soils, rather than on differences in fertility. Accordingly, superphosphate, ammonium sulfate and potassium chloride were added to all soil plots in the amounts recommended for normal greenhouse culture. No organic matter was added. During the experiment, Spurway soil tests of the upper and lower sections of the soils indicated that the three major elements, nitrogen, phosphorus and potassium, tended to accumulate at approximately the same rates for each element, at the surface of the four soils. Apparently, the nutrients were carried upward in the capillary water and deposited at, or near the surface by evaporation. At the conclusion of the experiment, soil tests showed that the major elements were at approximately the same levels in all four soils.

TABLE IV—Growth and Flowering Behaviour of Stocks, Var. Lilac Lavender, on Four Iowa Soil Types When Sub-Irrigated by the Constant-Level Method

Soil	Average Height of Plants (Inches)	Average Stem Length (Inches)	Average Length of Inflorescence (Inches)	Average No. of Flowers and Buds
Monona	29.7	19.3	10.3	37.8
Carrington	28.8	19.2	9.6	37.1
Webster	28.7	19.0	9.7	37.9
Clinton	26.8	17.2	9.7	35.7

Throughout the experiment, the tension with which water was held by the soils, as measured with a tensiometer, remained at, or near zero, indicating uniform wetness of the soils. The plastic and cohesive nature of the Clinton loam was definitely noticeable under prolonged wet conditions, in comparison with the other soil types used in this experiment.

TABLE V—Growth and Flowering Behaviour of Two Varieties of China Asters on Four Iowa Soil Types When Sub-Irrigated by the Constant-Level Method

Soil	Royal Dark Lavender		Royal Shell Pink	
	Average Height of Plants	Average Diameter of Flowers (Inches)	Average Height of Plants	Average Diameter of Flowers (Inches)
Monona	48.2	3.18	48.2	3.81
Carrington	46.9	3.14	45.4	3.60
Webster	46.8	3.13	45.3	3.56
Clinton	46.6	3.15	42.8	3.55

Results and Discussion

The results obtained are shown in Tables IV and V.

Stocks:—There were highly significant differences in the average heights of stocks grown on the four soils. Monona silt loam produced plants with the greatest average height, followed closely by Carrington silt loam and Webster clay loam. The average height of plants on Clinton silt loam was significantly less than the other three soil types. Average stem lengths varied in the same order, with the differences even more highly significant. There were no significant differences in average lengths of inflorescences, but in the production of number of flowers and buds per inflorescence, the plants on Clinton silt loam were definitely inferior.

China Asters:—The pink asters showed significant growth differences and the results parallel those secured in the stocks experiment. The lavender asters also showed growth variations on the four soils that confirm the stocks data, but the differences were not great enough to be significant.

In both experiments plant growth was very vigorous on all soils. This was probably due to the fact that water and nutrients were never limiting factors. The average length of the inflorescence of the stocks, when 10 florets had expanded, was 10 inches and each floret was of unusual size. Average heights of the single-stemmed China asters varied from 4 feet on the Monona soil to 3½ feet on the Clinton silt loam.

The role of organic matter as a source of gradually released nutrients was assumed to be minimized in this study by the incorporation of inorganic nutrients in the four soils. The buffering action of organic matter was believed to be negligible, although it should not be overlooked. An increase in soil aggregation results in an increase in macropore space, which is responsible for the major part of the aeration of soils. The increased soil aeration thus indirectly provided by high organic matter content, apparently counter-acted, in some measure, the adverse affects of extreme soil wetness induced by constant-level sub-irrigation. This apparently resulted in better growth of plants on the Monona, Carrington and Webster soils and was definitely a limiting factor in the case of Clinton silt loam. It is interesting to note that Monona and Clinton silt loams both have the same origin, that is, both are weathered from loess, and both have approximately the same

proportions of sand, silt and clay. In both soils the three major elements were at approximately the same levels. The one major difference in the soils, namely, the amount of organic matter, with its effect on structure and porosity, appears to be responsible for the superior behaviour of the Monona soil under the conditions of this study.

SUMMARY

The three Iowa soils having over 5 per cent organic matter, Monona silt loam, Webster clay loam and Carrington silt loam, produced significantly better crops of stocks and pink China asters than Clinton silt loam with only 2 per cent organic matter.

Under sub-irrigation Clinton silt loam was especially plastic, cohesive and difficult to handle, with the other soil types somewhat less so. Probably, incorporation of organic matter would have reduced the plasticity of all of these soils and made them more porous and easier to handle. It is also possible that the conventional method of sub-irrigation, involving the use of a tensiometer and permitting partial drying of the soil, would react more favorably with these soil types. Such studies are in progress.

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Observation on Gardenia Flower Production at High Air and Soil Temperatures

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In the course of investigations dealing with factors influencing the abscission of Gardenia buds, one of the factors under observation was soil temperature. Second year gardenia plants of *Gardenia jasminoides* . . Hadley were grown in wooden boxes 4 feet by 1 foot by 6 inches, two plants to each box in which the growing medium was a mixture of one-half peat and one-half soil. Six boxes were placed across a concrete bench in such a way that each end of a box rested on the upper edge of an 8-inch bench side. Two steam lines of ¾-inch pipe were placed on the bottom of the bench parallel to the length. This allowed 6 inches of clearance between the pipes and the boxes. To retain the heat around the soil the space between boxes was covered tightly with an insulating material known as Fiberglas. The soil surfaces of the boxes were not covered in order to facilitate watering. By this means the soil temperature of the plot was maintained at 78 to 84 degrees F.

A check plot of similar boxes was placed adjacent to the heated plot. All surfaces of the check plot boxes were exposed to the atmosphere of the greenhouse and the temperature of the soil fluctuated accordingly.

The experiment was started October 1, 1946 and was continued until May 15, 1947. An attempt was made to maintain the greenhouse night temperature at an average of 62 degrees F ± 2 degrees F for the period October 1, 1946 to December 1, 1946. At this time the night temperature was gradually raised to 70 degrees F. This practice is usually followed in commercial work to increase flower production during the Christmas holidays. Day temperatures were 5 degrees and 10 degrees higher than night temperatures on cloudy and sunny days respectively.

The abscission rate became extremely high on the high soil temperature plot with the result that 80.5 per cent of the buds which were separated from the plants during the month of December 1946 did so by abscission and did not reach anthesis. All the foliage on the plants in this plot became dark green in color. This was unlike the check plot where the growing tips retained their light green appearance. Jones (2) mentioned a similar condition with *Gardenia jasminoides fortuniana Vietch* when the plants were grown at temperatures of 20 degrees C or higher.

When the air temperature was again reduced to the original level on January 1, 1947, the foliage on the plants subjected to the higher soil temperature remained dark green and no further elongation of the stems took place. Buds which were on the plants at that time did not develop. The growth of the plants was definitely arrested although no part of the plants appeared to be injured in any way. This condition persisted until late March when the plants began to show evidence of shoot growth and flower bud development. During the period from

December 24, 1946 to May 1, 1947 only three flowers were cut from the 12 plants in this plot. Eight buds abscissed during the same period.

As can be seen from results in Table I that flowering was greatly reduced by such treatment.

TABLE I—FLOWER PRODUCTION OF TWO-YEAR GARDENIA PLANTS (OCTOBER 1, 1946 TO MAY 15, 1947)

	Total Flowers	Flowers Per Plant
Check plot	588	49.00
High soil temperature plot	146	12.17

Apparently, when the gardenia plants were subjected to high air and soil temperatures during a period when the light intensity was relatively low and of short duration, the plants assumed for all practical purposes a "dormant" condition.

In another part of the same greenhouse 24 boxes of first-year gardenias were being grown. These had been planted during May 1946, three to a box in the same type boxes and soil mixture as previously mentioned. The boxes were placed on the bench in a manner similar to that previously described and occupied approximately 48 feet of a 60 foot bench. Overhead steam pipes connecting the heating pipes of the house to a motorized control valve were located over the first six boxes on the bench. These pipes were approximately 6 feet above the soil surface. As the plants grew the distance between the tops of the plants and the steam pipes decreased to 2½ to 3 feet by December.

During the December forcing period, the plants in the six boxes beneath the pipes plus three to four additional ones showed a growth condition similar to that described previously in the high soil temperature plot. There was no sharp line of demarcation between boxes of plants showing the dark green color and those not so affected, however, there was a gradual lightening of the green color of the growing tips from the sixth to eleventh box. Beyond the eleventh box the color of growing tips was about the same for all boxes. No excessive abscission appeared to take place on those plants which became dark green but since actual counts were not made this could not be substantiated.

Arthur and Harvill (1) showed that plants of *Gardenia veitchii* could be made to react in a similar manner and when the dark green plants were placed in cool temperature (60 degrees F) there would be growth of shoots and development of flowers already present.

Table II is a compilation of flower production of the 1-year plants.

The plants did not respond to the cooler temperature supplied after January 1, 1947 so it was decided that additional recording instruments should be placed throughout the greenhouse to determine what variation in temperature and humidity might be present. Thermohumidigraphs placed at a level with the tops of the plants showed that plants growing well during late February and March were subjected to an average night temperature of 64 degrees F, and 75 per cent relative humidity. Plants growing under the steam pipes were subjected to an average night temperature of 68.5 degrees F, and 65 per cent

TABLE II—Production of One-Year Gardenia Plants (October 1, 1946 to May 19, 1947)

Box No.	Culls	Small (2¼-3 Inches)	Medium (3-3½ Inches)	Large (3½ Inches +)	Total	Flowers Per Plant
1	0	2	3	1	6	2.00
2	0	0	1	5	6	2.00
3	0	0	3	3	6	2.00
4	0	0	2	7	9	3.00
5	1	1	5	9	16	5.33
6	0	5	11	23	39	13.00
7	0	4	17	39	60	20.00
8	3	3	18	45	69	23.00
9	3	6	34	47	90	30.00
10	1	12	23	77	113	37.67
11	1	5	26	57	89	29.67
12	2	6	24	53	85	28.33
13	0	3	17	59	79	26.33
14	1	11	38	49	99	33.00
15	0	10	27	56	93	31.00
16	2	3	14	72	91	30.33
17	1	5	20	66	92	30.67
18	1	10	40	48	99	33.00
19	1	14	27	51	93	31.00
20	0	8	22	54	84	28.00
21	2	6	23	83	114	38.00
22	1	13	28	72	114	38.00
23	0	9	36	62	107	35.67
24	0	14	34	92	140	46.67

relative humidity. Those plants supplied bottom heat had an average night temperature of 67 degrees F, and 69 per cent relative humidity around their tops.

Soil temperatures of the 2-year-old plant check plot, good growing 1-year-old plants and dark green 1-year-old plants exhibiting arrested growth symptoms fluctuated between 61 and 67 degrees F according to weather conditions. They all showed approximately the same temperature at any given time. It would seem that there must be a critical temperature range between 65 degrees and 70 degrees F, which under light conditions of low intensity and short duration caused a decided inhibition of growth. Since this condition does not appear during summer months when high temperatures and long periods of light of high intensity prevail, it appears that the critical temperature range would be governed largely by day length and light intensity. Whether air or soil temperature is the most important in this respect would necessitate further study to prove. It seems plausible that under low light intensity and short-day conditions either an extremely high air or soil temperature may cause the above condition to develop in the gardenia. Likewise, a combined moderately high temperature around both tops and roots of the plants might also give similar results.

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Soil Nitrate Levels for Roses[1]

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MANY florists are using the results of rapid soil tests to determine the time and amount of application of nitrogen fertilizers for the production of roses. It, therefore, is desirable to know the nitrate levels to be maintained for optimum production and quality. Seeley (4) grew roses in soil with nitrate levels ranging from 2 to 50 ppm and found that production increased with each increment of nitrate up to 50 ppm but the difference in production with 25 and 50 ppm was not significant. The average stem length was nearly the same in all treatments, being slightly greater with the higher soil nitrate levels.

Post and Howland (3) in a similar experiment, grew roses with soil nitrate levels of 10 to 100 ppm. Production increased with each increment of nitrate up to 100 ppm. The rose production was significantly decreased from the maximum when the nitrate level was about 25 ppm or lower during two seasons and below 10 ppm during a third season. The stem length was approximately the same with all nitrate levels.

Because in the previous studies a nitrate concentration high enough to cause retardation of growth was not maintained, the present investigation was made to study the growth and production of roses grown with soil nitrate levels of 50, 100, 200, 300 and 400 ppm.

MATERIALS AND METHODS

Dormant started-eye budded plants of the variety Briarcliff were pinched for the first 2 months and then were maintained in continuous production. After planting, 4 months were required to increase the highest soil nitrate levels to the desired concentration; therefore, production data were recorded from November 1945 to April 1947. No records were obtained in May and June 1946 because of a fumigation "burn" which injured some of the young shoots in early May.

The method of culture was similar to that of the previous experiments (3, 4), the plants being grown in water tight plots with nine plants in each 3- by 3-foot plot and four plot replications per treatment.

The soil was a Genesee silt loam composted with 25 per cent by volume of manure. Superphosphate (20 per cent) at the rate of 5 pounds per 100 square feet of bench area was incorporated in the soil before planting. Subsequent applications of superphosphate, muriate of potash and hydrated lime were made to maintain the phosphorus test between 3 and 8 ppm, potassium from 18 to 50 ppm, and the pH between 5.3 and 6.7. Beginning in July ammonium nitrate in solution was applied to the soil every third day in order to establish the desired nitrate levels. All drainage water was collected and returned to the plot in the next watering; thus none of the nutrients were lost by leaching.

[1]Appreciation is expressed to Fred Horton and his assistants for their help in culture of the plants and to Iva E. Piper who tested the soils.

The soil in each plot was tested twice each month by extracting with the Spurway (5) extracting solution and determining nitrates by the phenoldisulfonic acid method. The results of the analyses were expressed as parts per million (ppm) of nitrate (NO_3) in the soil extract.

Flowers were cut each morning and the stems graded by 3-inch increments. Flowers were considered salable if the flower and foliage showed no defects or chlorosis, and if the stem was at least 9 inches in length.

RESULTS

Nutrient Levels:—The desired and actual nitrate levels in the soil are presented in Table I. It was difficult to maintain high nitrate levels in soil with little deviation from the level desired, and it may be seen that the soil nitrate concentrations were in general higher than desired.

TABLE I—RANGE OF NITRATE CONTENT OF THE SOIL

Ppm of Nitrate in the Soil Extract		
Desired	1945–46 Season	1946–47 Season
50	50–100	50–100
100	95–150	90 155
200	165–266	180–250
300	275–420	270–375
400	380–523	375–520

Flower Production:—The data in Table II show that in both seasons the production of salable flowers was greatest in the lowest nitrate treatment with decreases in production as the nitrate increased. The decrease with the 100 (actually 90 to 155) ppm treatment was not significant during the first season but was highly significant in the second season. The actual nitrate tests giving the highest production ranged from 50 to 100 ppm, whereas the next highest treatment with 90 to 155 ppm showed a decrease in production which was highly significant during the second season. It is interesting to note that the production of unsalable flowers increased as the soil nitrate content increased so that the total production in the various treatments was not greatly different especially during the first season.

TABLE II—EFFECT OF SOIL NITRATE LEVELS ON ROSE PRODUCTION

Nitrate Level (Ppm)	Ave No. of Flowers Per Sq Ft Nov 1, 1945 to Apr 30, 1946 (6 Months)			Ave Stem Length of Salable Flowers (Inches)	Ave No. of Flowers Per Sq Ft Jul 1, 1946 to Apr 30, 1947 (10 Months)			Ave Stem Length of Salable Flowers (Inches)	Diameter of Fully Opened Flowers* (Inches)
	Salable	Unsalable	Total		Salable	Unsalable	Total		
50	10.3	0.1	10.4	22.7	29.5	0.7	30.2	21.6	4.03
100	8.8	0.2	9.0	23.1	25.1	0.4	25.5	18.1	4.13
200	8.4	0.3	8.7	21.5	25.1	0.9	26.0	17.1	4.02
300	6.9	2.4	9.3	18.8	23.0	3.8	26.8	16.1	3.44
400	5.1	4.9	10.0	18.3	17.5	7.6	25.1	13.0	3.28
Least significant difference at 5 per cent level (Snedecor)	1.8				2.3				

*Average of 50 flowers.

There was no difference in the keeping quality of the roses grown at the various nitrate levels.

Stem Length and Flower Size:—The average stem length decreased as the soil nitrate concentration increased (Table II). There was little difference in size of flowers at the 50, 100 and 200 ppm levels, but flowers in the 300 and 400 ppm treatments were smaller than those with lower soil nitrate concentrations.

Seasonal Production:—The production data in Table III show that the production of roses was greater during the summer months than in the winter, no matter what nitrate level was maintained in the soil. The large production in July was partially caused by a heavy crop after the fumigation injury in early May. This decrease in rose production during the winter months which was also demonstrated in the two previous experiments (3, 4), and the nitrate studies of Hubbell (2) emphasize the importance of light as a factor in rose production.

TABLE III—EFFECT OF NITRATE LEVEL ON THE MONTHLY PRODUCTION OF ROSES

Nitrate Level (Ppm)	Average Number of Salable Flowers Per Square Foot									
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
					1945–46 Season					
50	—	—	—	—	1.25	1.56	1.61	0.67	2.58	2.58
100	—	—	—	—	0.78	1.25	1.53	0.56	2.08	2.56
200	—	—	—	—	0.56	1.53	1.25	1.06	1.97	2.00
300	—	—	—	—	0.83	0.69	1.11	0.97	1.56	1.75
400	—	—	—	—	0.81	0.72	0.50	0.42	0.94	1.69
					1946–47 Season					
50	7.39	2.97	3.47	5.08	1.50	2.19	1.22	2.17	1.83	1.72
100	6.03	3.03	2.42	4.75	1.61	1.58	1.22	1.72	1.64	1.14
200	5.42	3.28	2.86	4.50	1.86	1.44	1.56	1.25	1.78	1.17
300	4.08	2.28	2.61	5.03	2.00	1.50	1.39	1.25	1.56	1.25
400	3.00	2.11	1.81	3.17	2.08	1.06	0.97	0.75	1.56	1.00

Symptoms of Excess Nitrogen:—Although flower production and stem length were reduced with soil nitrate levels of 90 to 250 ppm, there was no visible injury to the plant except a slight retardation in growth. The size and color of the leaves and flowers were normal. In November 1946, 3 weeks after the nitrate levels had been adjusted, plants of the 300- and 400-ppm treatments exhibited the first visible symptoms of excess nitrogen by developing yellow and yellow-green leaves with dark green veins. This was a typical iron chlorosis, and probably due to insufficient absorption of iron by the plant because of root injury caused by the excess soil nitrogen. Later, some of the young shoots developed a pink or slight reddish color. Older leaves became necrotic along the edges, followed by death of the entire leaf and abscission of these leaves.

None of the plants with these high nitrate levels were completely killed. In fact, even after 18 months growth, not all of the shoots on these plants were chlorotic, and some salable roses were still being produced.

TABLE IV—Amount of Nitrogen Applied to Maintain Definite Soil Nitrate Concentrations

Date of Experiment	Soil Nitrate Level (Ppm)	Grams of Nitrogen Applied Per 100 Square Feet Per Month				
		First Season		Second Season		Third Season
		Nov 1 to Mar 1	Mar 1 to Nov 1	Nov 1 to Mar 1	Mar 1 to Nov 1	Nov 1 to Mar 1
1942 to 1945	25	3.4	30.6	39.0	54.7	35.2
	50	13.0	42.6	52.8	77.9	41.8
	100	31.8	62.6	74.6	90.2	64.8
1945 to 1947	50–100	5.1	27.5	15.0	—	—

Discussion

Seeley (4) found that there was an increase in rose production with each increment of nitrates up to 50 ppm and production dropped off significantly at some point between 10 and 25 ppm. The nitrate level had no effect on length of stem. The data of Post and Howland (3) showed an increase in production of salable roses as the soil nitrate level increased from about 10 ppm up to 100 ppm. The actual soil tests and their data showed that during two seasons the production dropped off significantly with nitrate levels averaging about 30 ppm. During the other season, there was a significant decrease with 10 ppm. In the present investigation the optimum production and stem length were obtained with soil nitrate levels ranging from 50 to 100 ppm, whereas higher levels decreased production and stem length. On the basis of the data of these three experiments, the soil nitrate level should be maintained between 25 and 100 ppm for optimum production and stem length. This can best be done commercially by allowing the soil nitrate level to drop to 25 ppm, adding sufficient nitrogen fertilizer to raise the nitrate level to 100 ppm, and then allowing it to drop to 25 ppm before the next application.

In all of these experiments, the soil nitrate concentrations that gave the highest production in summer also produced the most flowers in winter. Therefore, the optimum range of 25 to 100 ppm should be maintained at all seasons. The amount of fertilizer required will, however, vary with the seasons with less fertilizer being required to maintain the optimum levels during the winter months when the plants grow less than the other seasons. Seeley (4) showed that during the months of December to February, considerably less fertilizer was needed than in the spring and fall months to maintain the same soil nitrate concentration. Davidson (1) found that mature rose plants in nutrient culture absorbed 35 grams of nitrogen per 100 square feet per month from November 1 to March 1 and 61 grams per month during the period of March 1 to November 1. The quantity of nitrogen added to the soil for optimum growth and production in the 1942 to 1945 and 1945 to 1947 nitrate experiments are presented in Table IV. During the winter months considerably less nitrogen was applied than during the other seasons. The amounts of nitrogen applied to maintain 25 ppm during the second and third seasons are very similar to the amounts absorbed by mature plants in Davidson's investigations;

to maintain the higher levels, more nitrogen had to be applied. It should be noted, however, the amounts of nitrogen applied during the first season were much less than during the second and third seasons. This is probably due largely to liberation of nitrogen upon breakdown of the organic matter in the soil. Also the plants were smaller during the first season, thus requiring less nitrogen. In the 1945 to 1947 experiment the same general relationship exists but the nitrogen applications were much less than in the previous experiment.

These data indicate that the amount of nitrogen that need be applied with a new soil containing considerable organic matter during the first season is less than during subsequent seasons and that less fertilizer need be applied in winter months than in the other months to maintain the same soil nitrogen concentration.

Summary

Roses were grown with soil nitrate levels of 50 to 525 ppm. Production of salable flowers, and stem length were optimum between 50 and 100 ppm. Analysis of these data and those of the two previous nitrate experiments (3, 4) showed that maximum rose production was obtained with 25 to 100 ppm of nitrate in the soil.

Flower production during the winter months was less than during the other seasons, again demonstrating the importance of light in rose production.

Less fertilizer is required to maintain optimum nitrogen levels during winter as compared to other months, and less need be applied during the first season than in subsequent seasons.

Symptoms caused by excess soil nitrogen were described.

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Growth Responses by Kalanchoes to DDT and Other Synthetic Compounds

By David V. Lumsden and Floyd F. Smith, *U. S. Department of Agriculture, Beltsville, Md.*

Kalanchoes are becoming increasingly popular as pot plants for sale during the winter (1). These plants may be attacked by a number of pests, including thrips, which are readily controlled on most crops by applications of DDT. However, reports of serious damage to kalanchoes in commercial greenhouses following applications of DDT have come to the attention of the writers. The injury symptoms are slow to develop, as a rule, but from 1 to 3 weeks after exposure to DDT, kalanchoe foliage starts to lose chlorophyll, epinasty develops, and leaves abscise and fall until in some cases the plant is completely defoliated. Death frequently ensues, or with less extreme damage recovery is very slow. Usually it is unprofitable to attempt to bring such plants back to normal. Blauvelt (2) briefly described the extreme susceptibility of kalanchoes to DDT wettable powder sprays and emulsions and warned against such treatment of this crop.

It is well recognized that plants vary in their susceptibility to DDT applications. However, the detailed effects of this chemical on various crops are not yet fully known. Moon and Harley (5) give evidence that DDT sprays do not impair leaf efficiency of apple trees under the conditions of their experiment. Brown and Alban (3), however, report varying injury by DDT sprays to some of the cucurbits and list only 11 varieties out of 42 that recovered sufficiently to produce a satisfactory crop. Hervey and Schroeder (4) reported severe stunting of the Ohio 31 variety of cucumber and no injury on China or Chicago Pickling varieties by DDT dusts. Damage due to DDT sprays or dusts on cucumber showed mostly as dwarfing and marginal chlorosis of the leaves. The symptoms of injury on cucumber differ from those on kalanchoe.

In 1946 the writers applied a DDT aerosol in an experimental greenhouse for control of thrips on a number of crops, including *Kalanchoe globulifera coccinea.* The kalanchoe plants were severely injured. This aerosol contained a refined grade of DDT which had been safe on a wide variety of plants except cucumber. Injury to cucumber was found to be due to the cyclohexanone solvent (6). Studies were therefore planned in 1947 to determine whether the injury to kalanchoe was due to technical or refined DDT or to one of its isomers, and whether related compounds or other synthetic insecticides would cause similar injuries.

For these tests seeds of three kinds of kalanchoe were donated by George J. Ball, Inc., West Chicago, Illinois, marked as *Kalanchoe globulifera coccinea* (No. 24–74A); *Kalanchoe globulifera coccinea,* Tom Thumb (81–85A); and Kalanchoe variety Brilliant Star (No. 76–17). All of these appear to be referable botanically to *Kalanchoe blossfeldiana.* In this paper the three kinds are referred to under their trade names. Seed was sown on March 3, 1947, in vermiculite; on

April 23, the seedlings were potted into thumb pots and on June 12 shifted into 3-inch pots.

During the late summer and fall, three tests were made on the three kinds of kalanchoe mentioned above, to determine their tolerance to the various insecticides.

Included in the tests were a technical and an aerosol grade of commercial DDT that contained, respectively, 75 and 99 per cent of *p,p'* DDT; also pure re-crystallized *p,p'* DDT and *o,p'* DDT. Dusts containing 5 per cent of the active ingredient were prepared by mixing an acetone solution with pyrophyllite, evaporating to dryness and grinding. Suspensions containing 25 per cent of the active ingredient were prepared by the same procedure. A suspension was also prepared of the by-product oils left in the commercial preparation of the aerosol grade of DDT from technical DDT. The emulsions contained 0.5 pound of the active ingredient, 0.95 pint of methylated naphthalene, and 1.5 tablespoonfuls of polyethylene glycol monoisooctyl phenyl ether (Triton X–100).

To compare the effects of DDT on kalanchoes with the effects of certain chemicals that enter into the manufacture of DDT or are formed during the chlorination processes, emulsions of the technical grade and of the *p,p'* isomer of tetrachloro-diphenyl-ethane (TDE), of 2–trichloro–1–*p*–chlorophenylethanol (abbreviated as TCE, Table I), and of chlorobenzene were prepared and used as dips.[1] Emulsions

TABLE I—INJURIES ON KALANCHOE BY DUSTS, SUSPENSIONS AND EMULSIONS

Material Applied*	Plant Symptoms†					Remarks
	Epinasty	Leaf Fall	Foliage Yellowing	Tip Necrosis	Plants Killed	
DDT in 5 per cent dust						
Technical grade	S	S	S	S	No	Weak inflorescence
Aerosol grade	S	S	M	S	No	Stronger developing inflorescence
p,p' DDT	M	M	M	S	No	
o,p' DDT	O	M	M	M	No	
DDT in suspension						
Technical grade	S	S	S	S	Yes	
Aerosol grade	S	S	S	S	No	Inflorescence reappearing
By-product Oils	S	S	S	S	Yes	
p,p' DDT	S	S	S	S	No	
o,p' DDT	O	M	M	M	No	
DDT in emulsion						
Technical grade	S	S	S	S	Yes	
Aerosol grade	S	S	S	S	Yes	
p,p' DDT	S	S	S	S	No	Weak new growth
o,p' DDT	M	S	S	M	No	
TDE in emulsion						
Technical grade	S	S	S	S	Yes	
p,p' TDE	O	O	S	S	No	
TCE in emulsion	O	O	O	O	No	Brown necrotic leaf spots
Chlorobenzene in emulsion	O	O	O	O	No	
Emulsion check	O	O	O	O	No	
Untreated check	O	O	O	O	No	

*Suspensions and emulsions diluted to contain 0.5 pound of the active ingredient per 100 gallons
†O, M, S, indicate NO, MODERATE, AND SEVERE symptoms, respectively.

[1]The writers appreciate the interest in this problem of Elmer E. Fleck, Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine, and his furnishing of several chemicals.

were also prepared to include chlorinated camphene, chlordan, or benzene hexachloride, each with 0.5 pound of the active ingredient per 100 gallons, except that the technical benzene hexachloride emulsion contained 0.1 pound of the gamma isomer per 100 gallons. Tetraethyl pyrophosphate and hexaethyl tetraphosphate were diluted 1–1600 in water.

In each dust treatment approximately 1 gram of dust was applied to five plants. Other plants were dipped in the emulsions and suspensions, which had been diluted with water to give 0.5 pound of the active ingredient per 100 gallons. Control plants were dipped in an emulsion of the solvent and emulsifier but without active ingredient.

The results of three series of tests on *Kalanchoe globulifera coccinea* are summarized in Table I, and in the following discussion. The symp-

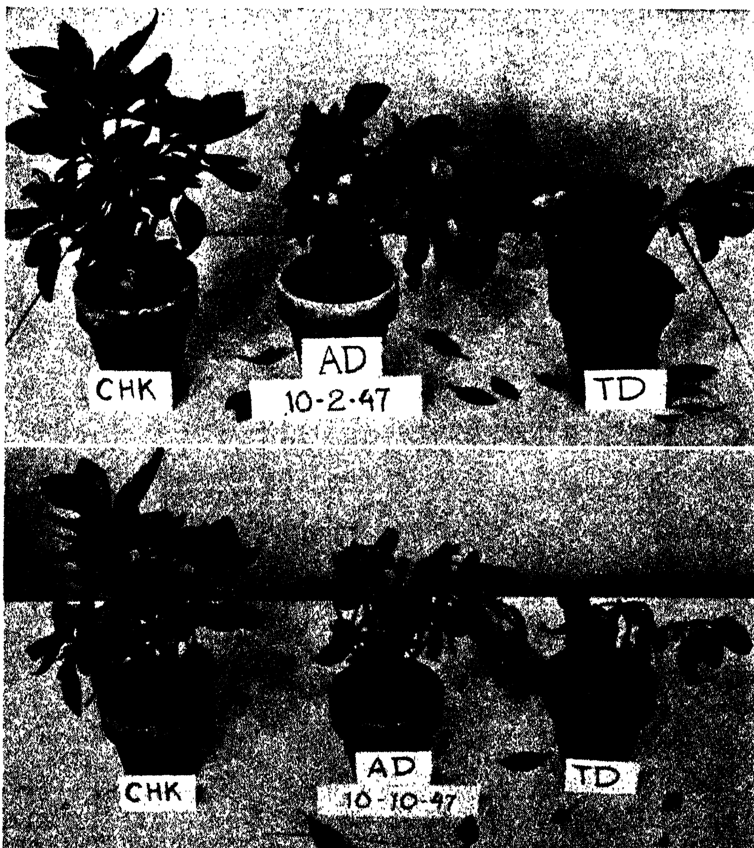

FIG. 1. Characteristics and progress of injury to *Kalanchoe globulifera coccinea* var. Tom Thumb treated with DDT on September 16, 1947. Condition October 2 (upper) and on October 10 (lower). Plants from left to right: Check, aerosol DDT dust, technical DDT dust.

toms of epinasty, leaf fall, and necrosis became evident in 10 to 12 days and progressed rapidly for the next 2 weeks (Fig. 1). Plants that survived for 6 weeks produced weak but normal inflorescences, thus indicating that the effect of the chemical had dissipated. The most severe injury resulted from emulsions, less from suspensions, and least from dusts. In dusts and suspensions, the technical grade DDT caused more rapid epinasty and killing of terminal growth than the aerosol grade DDT, but in emulsions these two grades produced approximately equal injury. In suspensions, the by-product oils were similar to technical DDT in effect. The *p,p'* DDT caused severe epinasty, leaf yellowing, and leaf abscission, but less necrosis than the technical or the aerosol grades of DDT. The *o,p'* DDT caused almost no epinasty and only slight leaf fall and leaf yellowing. The emulsion of technical TDE caused severe epinasty and other symptoms, as did the technical DDT; but *p,p'* TDE caused only moderate killing of tips. Emulsions of 2–trichloro–1–*p*–chlorophenylethanol and of chlorobenzene caused no injury. Small necrotic spots developed on the youngest leaves of plants dipped in chlordan emulsion. No change in growth appeared on plants dipped in emulsions of chlorinated camphene and of benzene hexachloride, or in solutions of tetraethyl pyrophosphate and of hexaethyl tetraphosphate.

The Brilliant Star kalanchoe was less responsive to DDT formulations than were *Kalanchoe globulifera coccinea* and its dwarf variety, Tom Thumb. Epinasty was evident in the plants dipped in emulsions containing the technical or aerosol grades of DDT or the *p,p'* DDT. Yellow spotting developed on leaves of plants dipped in an emulsion of either the technical or pure *p,p'* TDE. Brown necrotic spots on leaves and stems and epinasty occurred on plants dipped in an emulsion of 2–trichloro–1–*p*–chlorophenylethanol. Since typical epinasty did not occur in the more responsive *Kalanchoe globulifera coccinea* plants in the same test with the last named material, it is possible that the bending of the stems in Brilliant Star variety may have been a further effect of the necrotic stem lesions rather than a growth-regulator effect.

These tests indicate that the growth-regulator activity and the plant toxicity of DDT to kalanchoe is due to the higher chlorinated compounds produced during synthesis and not to the less completely chlorinated compounds or to the basic ingredients that enter into its manufacture. None of the isomers of DDT, or of TDE, are safe to use on *Kalanchoe globulifera coccinea*. Other insecticides, including chlorinated camphene, benzene hexachloride, hexaethyl tetraphosphate, and tetraethyl pyrophosphate, appear to be safe to use on this plant. Chlordan in an emulsion caused moderate injury that would preclude its use.

The extreme sensitivity of *Kalanchoe globulifera coccinea* to DDT suggests the possible usefulness of this plant in the detection of small quantities of this compound.

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Cost Comparisons — Soil and Gravel-Grown Carnations

By August Mussenbrock and George Beach, *Colorado A. and M. College, Fort Collins, Colo.*

The purpose of this experiment was to determine the cost of production of carnations in soil as compared to gravel culture.

Material and Methods

Two benches, each 4 feet by 36 feet were used. These were side by side in the center of the same house. Plants of Spectrum Supreme were set 7 inches by 8 inches on June 9. Pasteurized virgin soil (pH 6.5) with 5 pounds per 100 square feet of treble superphosphate incorporated before planting was used on the soil bench. Washed gravel, (1/8- to 3/8-inch) was used on the gravel bench. A modified WP solution was used (phosphate 100 ppm and potash 250 ppm). For the first week after planting, a 1/2 WP solution pumped only once a day was used. A paper mulch (6-inch wide strips of wrapping paper, laid lengthwise and crosswise on the gravel surface) was applied just after planting. This reduces gravel temperature and prevents excessive evaporation.

A side bench of the same surface area as the gravel center bench in this test, was connected to it, so as to be pumped simultaneously, using the same equipment.

A record was kept of the cost of all operating expense on each of the two center benches in the test. The extra side bench in gravel was not in the test, but all costs for solution maintenance and pumping were charged against the center bench.

All tests of soil and nutrient solutions were made by the Spurway method and soil was maintained at the following levels: nitrate nitrogen 10 to 20 ppm; phosphate, 12 to 15 ppm; potash, 25 to 30 ppm, and pH 6.5 to 7.0.

In addition to two manure mulches, four applications of sodium nitrate at a rate of 1 pound per 100 square feet were made to the soil bench. Early in February an application of potassium chloride at the same rate was applied.

The pumping schedule used on the gravel was:

May 1 to Sep 30 — two pumpings per day
Sep 30 to Dec 15 — one pumping per day
Dec 15 to Feb 20 — one pumping every other day
Feb 28 to Apr 30 — one pumping per day
(Weather conditions altered this schedule occasionally)

After rooting in sand, plants for the soil bench were grown in soil prior to benching. Those for the gravel bench were grown in a washed coarse sand.

Plants in both soil and gravel were pinched twice after benching. The last pinch was July 15 to insure an early crop.

Seven spray applications were made during the early part of the growing season combating thrip and red spider. "Plant Spray" and "Loro" insecticides were used according to the manufacturer's recom-

mendations, on the soil bench. Plant Spray was substituted for Loro on the gravel bench. When the plants were well established sodium selenate in the P4O form was applied to the soil bench at the rate of 3 pounds per 100 square feet.

On the gravel bench sodium selenate (crystal) was applied at the rate of 10 ppm (10 grams in the 1000 liter tank) each week for 3 weeks in late July and early August.

In early October an Azobenzene fumigation with Benzofume was necessary for good red spider control.

The experiment ended May 31, at which time both benches were at the height of production.

Results

Tables I and II show the operating expense per 100 square feet on each bench. The following overhead items are, of course, chargeable to cost of production, but are identical for both benches and have not been listed in the tables:

Fuel and operation of heating plant.
Maintenance and repair of greenhouses and equipment.
Cost of distributing, harvesting, grading, packing and transporting to market.
Cost of selling or marketing, losses.
Water, electricity, tools.
Management.
Offices (labor and supplies).
Taxes, insurance, interest, depreciation, and so on.

A considerable check in growth was noted 3 and 4 weeks after the application of sodium selenate. Instead of stretching upward, excessive branching resulted in the lower part of the plant. Somewhat later, branches with 5 and 10 well developed side shoots were frequently noted, particularly on the outside rows of the bench. Some injury of

TABLE I—Soil Bench (All Labor Costs Shown in the Tables Are at the Rate of $1.00 Per Hour)

	Debit	Credit
Non-Expendable Item		
Bench $2.00 per lineal foot $72.00		
Operating Expenses Per 100 Square Feet Bench Area		
Soil, 1.8 cubic yard @ $3.00	$ 5.40	
Labor, wheeling and preparing soil	4.00	
Plants, 256 @ 15c each	38.40	
Planting and watering in	1.33	
Watering per season in hours, 24.83 hours	24.83	
Four cultivations	1.83	
Seven spray applications	1.50	
Six soil tests	4.00	
Fertilizing and mulching	1.83	
Topping	1.33	
Erecting plant supports and stringing	4.00	
Production		
881 First @ 15c		$132.15
889 Shorts @ 12c		106.68
286 Thirds @ .8c		22.88
191 Splits @ 6c		11.46
Total	$88.45	$273.17
(8.9 flowers per plant) Balance		184.72

TABLE II—GRAVEL BENCH

		Debit	Credit
Non-Expendable Items			
Bench $4.00 per lineal foot	$144.00		
Gravel, 2.7 cubic yards @ $3.00	8.10		
Tank	25.00		
Equipment	50.00		
Installation	25.00		
Total	$252.10		
Operating Expense Per 100 Square Feet Bench Area			
Labor, wheeling and preparing gravel		4.00	
256 plants @ 15c		38.40	
Planting		1.33	
Fertilizer (commercial) 32 pounds		1.63	
Six solution changes		2.66	
Three tank cleanings		2.00	
Sixteen solution tests		1.83	
Adjustments		1.83	
Water level adjustment per season, 5⅓ hours		5.33	
Mulching		0.66	
Topping		1.50	
Seven spray applications		1.50	
Erecting supports complete		4.00	
Electricity 18c per month		2.16	
Production			
839 Firsts @ 15c			125.85
1,250 Shorts @ 12c			150.00
441 Thirds @ 8c			35.68
160 Splits @ 6c			9.60
2,690 (10.5 flowers per plant) Totals		$68.83	$321.13
Balance			$252.30

this type was noted on the soil bench, but was less severe and occurred later.

The stem length was severely reduced and less No. 1 flowers were cut during the first cutting period. The second crop of flowers were of normal stem length.

The plants in the sodium selenate treated benches were free of red spider throughout the experiment. Similar plantings in carnations in the same houses, but not included in the trial and not subject to the sodium selenate treatment were showing signs of reinfestation the latter part of February. The injury is further demonstrated by comparing the production of short stemmed flowers to first grade flowers in the two benches. This would indicate that the rate of intake of selenium is less rapid in soil, than in a nutrient solution. A carnation cutting specialist may benefit considerably using sodium selenate to increase cutting material.

The pH of the soil during the winter months dropped gradually from 6.5 to 4.3. Agricultural lime applied at the rate of 6 pounds per 100 square feet raised the pH to 7.2, after which it gradually lowered again to a pH of 6.0 at the end of the season.

The soil-grown plots produced 8.9 flowers per plant against the gravel grown 10.5 per plant. The difference of 1.6 flowers per plant in favor of the gravel method may not be significant because of the sodium selenate treatment for both plots. The soil plot received the full amount ¼ gram per square foot and no changes could be made thereafter. In the gravel plot the treatment was discontinued as soon as injury was noted.

Discussion

Tables I and II show total operating costs of $68.83 for gravel and $88.45 for soil. The difference is $19.62 per 100 square feet of bench area in favor of gravel. The essential difference in costs in the two methods is the cost of watering. In this test, one man-hour per linear foot of bench was required to water the soil bench for the entire season ($25.00 per 100 square feet on a 4 foot bench) while 18¢ per month for electricity did the same work on the gravel bench.

Summary

In comparing the cost of growing carnations in soil and in gravel operating costs were 28 per cent higher in soil than in gravel, or $19.62 more per 100 square feet of bench area. Overhead costs and non-expendable items are not included here.

Gravel-grown plants averaged 10.5 flower per plant October 1 to May 31. Soil-grown plants averaged 8.9 flowers for the same period.

Azofume and selenium controlled red spider, but selenium in the nutrient solution shortened flower stems.

The Influence of Soil Acidifying Techniques on the Growth of Azaleas[1]

By Roma D. Ballhorn and E. C. Volz, *Iowa State College, Ames, Ia.*

The soils of Iowa present a difficult problem to the growers of azaleas and related acid-tolerant plants requiring iron in a readily available form because they do not flower normally in calcareous and high lime soils. As a result, both amateur and commercial horticulturists are definitely interested in improved soil acidifying methods. A survey of previous work in the culture of azalea and other plants which require an acid soil, reveals that several factors must be taken into consideration. Volz and Stenstrom (5) have indicated that greenhouse soils can be greatly modified by the addition of various forms of humus, sand and fertilizer to the extent that the soil often loses its original character. Burk (2) has reported that alkaline water used for watering greenhouse plants also modifies the soil reaction and with azaleas and similar plants may constitute a serious problem. Constant irrigation with alkaline water gradually raises the pH of acid soils to 7.5 or higher. Some of the essential requirements for successful azalea culture as given by Bowers (1) are proper soil acidity, plenty of organic matter in the soil, adequate and satisfactory water relations along with a well-drained and aerated soil and proper nutrients. Wilde (6) found that the base exchange capacity of a soil could be improved by the addition of organic matter, particularly peat. According to Spurway and Wildon (4) the control of the pH is simplified when a soil is buffered by natural acids and they recommend the use of various acidifying elements such as sulphur or aluminum sulphate and subsequent use of neutral or acidifying fertilizers. Laurie and Kiplinger (3) and others specify the use of peat alone or as part of a soil mixture in which to grow azaleas.

With the above in mind, it was decided to work on the problem from the standpoint of finding materials capable of producing and maintaining the proper soil acidity for the growth of greenhouse azaleas.

Procedure

Uniform, rooted cuttings of the Kurume azalea var. Coral Bells were received on June 1, 1945, from a commercial grower and planted immediately in flats of acid peat. On July 19 they were potted in 4-inch pots according to the treatments outlined in Table I. Peat obtained from two sources was used as the basis of the potting media. An Iowa hypnum peat with an initial pH of 5.5 and a Minnesota sphagnum moss peat with an initial pH of 4.5 were the two media employed in this experiment. For some treatments the peat was adjusted to various acid reactions by means of H_2SO_4 and H_3PO_4. Other plots received sulphur applications besides the adjustment of pH by means of the acids, others received fertilizers and still others were watered regularly

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with acidified water. Recommended commercial practices were followed in regard to temperature, watering, pinching, syringing, and so on. The plants were grown in a lath house until September when the lath covering was replaced with glass sash to permit a uniform night temperature of 50 degrees F. On January 25, the pots were moved into a greenhouse of 65 degrees F. After the first bloom, the plants were shifted into 5-inch pots in late April. The original treatments as outlined for 4-inch pots were repeated after the plants were shifted to the 5-inch pots. On June 4, 1946, (the second year) they were again placed outdoors in a lath house and the pots plunged to shoulder depth in the beds. Ten pots were used in each of the 27 treatments and the pots were arranged in double rows with five plants in each row. The plants when grown in greenhouse benches or in beds in the lath house were arranged in randomized and replicated blocks. In randomizing the treatments a table of random numbers along with a distribution table was employed. The numbers were taken consecutively from the table of random numbers and matched with those from the table of distribution of weights.

The pH of the soil was determined at the beginning of the experiment and after forcing, after shifting and after the summer's growth outdoors. Welcher's Universal No. 1 indicator was used for making the colorimetric pH determinations. Records were kept on the number of flowers per plant, foliage color, plant quality (based on commercial value) and pH of media. The treatments used in this experiment are shown in Table I.

TABLE I—CULTURAL PRACTICES TO CONTROL pH

Adjustment of pH of Potting Media

Treatment 1. Acid peat only (no treatment)
Treatment 2. ½ acid peat ½ Iowa peat (no treatment)
Treatment 3. Iowa peat only (no treatment)
Treatment 4. H_2SO_4 with Iowa peat to pH 4.0
Treatment 5. H_2SO_4 with Iowa peat to pH 5.0
Treatment 6. H_3PO_4 with Iowa peat to pH 4.0
Treatment 7. H_3PO_4 with Iowa peat to pH 5.0

Maintenance of pH by means of Sulphur in Iowa Peat

Treatment 8. H_2SO_4 to pH 4.0 plus 2 ounces sulphur per 25 pounds air dry peat
Treatment 9. H_3PO_4 to pH 4.0 plus 2 ounces sulphur per 25 pounds air dry peat
Treatment 10. H_2SO_4 to pH 4.0 plus 4 ounces sulphur per 25 pounds air dry peat
Treatment 11. H_3PO_4 to pH 4.0 plus 4 ounces sulphur per 25 pounds air dry peat

Maintenance of pH by Means of Fertilizers

(1. Ammonium Sulfate 1 ounce Ferrous Sulfate 1 ounce Monopotassium Phosphate 1 ounce in 5 gallons Water)
Treatment 12. Acid peat
Treatment 13. Iowa peat
Treatment 14. Iowa peat H_2SO_4 to pH 5.0
Treatment 15. Iowa peat H_3PO_4 to pH 5.0
(2. Aluminum Sulfate 1½ ounces, Ferrous Sulfate 1½ Ounces in 5 Gallons Water)
Treatment 16. Acid peat
Treatment 17. Iowa peat
Treatment 18. Iowa peat H_2SO_4 to pH 5.0
Treatment 19. Iowa peat H_3PO_4 to pH 5.0

Watering Only With Acidified Water

Treatment 20. Acid peat with H_2SO_4 acidified water (pH 4.0)
Treatment 21. Acid peat with H_2SO_4 acidified water (pH 5.0)
Treatment 22. Acid peat with H_3PO_4 acidified water (pH 4.0)
Treatment 23. Acid peat with H_3PO_4 acidified water (pH 5.0)
Treatment 24. Iowa peat with H_2SO_4 acidified water (pH 4.0)
Treatment 25. Iowa peat with H_2SO_4 acidified water (pH 5.0)
Treatment 26. Iowa peat with H_3PO_4 acidified water (pH 4.0)
Treatment 27. Iowa peat with H_3PO_4 acidified water (pH 5.0)

Results and Discussion

From Table II, it can be seen that although the pH of the potting media at the beginning of the experiment varied from treatment to treatment there was no great difference between them at the end of the summer's growth. Watering with acidified water did, however, maintain a fairly low pH.

TABLE II—pH of the Potting Media

Treatment No.	At Beginning of Experiment	Before Forcing Into Bloom	After Forcing Into Bloom	After Shifting Into Large Pots	At End of Summer's Growth
1	4.5	6.0	6.5	4.5	6.5
2	5.0	6.5	7.0	5.0	6.5
3	5.5	6.0	7.0	5.5	6.5
4	4.0	6.0	6.5	4.5	6.0
5	5.0	5.5	6.5	5.0	6.5
6	4.0	6.5	6.5	4.5	6.0
7	5.0	6.0	6.5	5.0	6.5
8	4.0	5.0	6.0	4.0	6.0
9	4.0	4.0	6.0	4.0	5.0
10	4.0	4.5	5.5	4.5	Dead
11	4.0	4.0	4.5	4.5	6.0
12	4.5	5.0	5.5	4.5	6.5
13	5.5	5.5	6.0	5.5	6.5
14	5.0	5.0	5.5	5.0	6.5
15	5.0	5.5	5.5	5.0	6.5
16	4.5	5.0	5.5	4.5	6.0
17	5.5	6.5	6.5	5.5	6.5
18	5.0	5.5	5.5	5.0	6.5
19	5.0	5.0	5.5	5.0	6.5
20	4.5	4.0	5.0	4.5	5.0
21	4.5	5.0	5.0	4.5	5.5
22	4.5	4.0	5.0	4.5	5.0
23	4.5	5.0	5.0	4.5	5.0
24	5.5	5.0	5.5	5.5	6.0
25	5.5	5.0	5.5	5.5	5.5
26	5.5	5.0	5.0	5.5	5.0
27	5.5	5.0	5.0	5.5	5.5

The growth records presented in the following tables are based on number of flowers per plant, foliage color and plant quality and were made during the fall of the second year. In pruning and shaping the plants, an attempt was made to get a well-balanced plant with a nicely rounded top. The number of flowers on each plant was recorded.

The color of the leaves was classified as dark green, light green, yellow-green to yellow and white. Each color class was given a number. Five was the number designated for the darkest green and, therefore, the most desirable foliage. One signified very pale or white foliage. Numbers between 1 and 5 represent gradations from white to dark green.

The quality of the plants as determined by their general appearance, vigor, color, form and size was graded on a basis of 5 points. Five signified a well-formed, vigorous plant, one, a very poor plant. The score on quality presented in the tables represent the average score of four qualified judges.

In Table III it may be seen that acid (Minnesota) peat is significantly superior to Iowa hypnum peat as a potting medium for azaleas. In a mixture of equal parts of acid peat and Iowa peat, the latter definitely neutralized the beneficial effects of acid peat. The difference in the origin of these two peats soils, the degree of acidity and the

TABLE III—COMPARISON OF ACID (MINNESOTA) PEAT WITH IOWA PEAT

Treatment Number	Treatment	Average No. Flowers Per Plant	Average Foliage Color Score	Average Score on Plant Quality
1	Acid peat	60.3	4.4	4.0
2	One-half Acid peat, one-half Iowa peat	49.1	2.4	2.5
3	Iowa peat	40.5	1.3	1.0

nature and amounts of essential nutrients available may help explain the significant differences in flower production and scores on foliage and plant quality.

The results shown in the Table IV favor H_2SO_4 over H_3PO_4 as a means of adjusting the pH of the potting medium. Unfortunately an error occurred in repotting the plants in treatment 4, in May when

TABLE IV—COMPARISON OF H_2SO_4 AND H_3PO_4 FOR ADJUSTING pH OF IOWA PEAT

Treatment Number	Treatment (Iowa Peat)	Average No. Flowers Per Plant	Average Foliage Color Score	Average Score Plant Quality
4	H_2SO_4 to pH 4.0	56.8	0.6	1.0
5	H_2SO_4 to pH 5.0	40.8	2.3	2.5
6	H_3PO_4 to pH 4.0	25.4	2.5	2.0
7	H_3PO_4 to pH 5.0	39.5	2.3	2.0

double the amount of H_2SO_4 was used. As a result, the color of the foliage and score on plant quality are not indicative of what would have happened had this error not been made. This explanation also holds true for treatment 10 (Table V).

TABLE V—COMPARISON OF QUANTITIES OF SULPHUR USED FOR THE MAINTENANCE OF pH IN IOWA PEAT

Treatment Number	Treatment (Iowa Peat)	Average No. Flowers Per Plant	Average Foliage Color Score	Average Score Plant Quality
8	H_2SO_4—2 ounces sulphur	40.7	4.7	3.2
9	H_3PO_4—2 ounces sulphur	48.3	4.3	3.5
10	H_2SO_4—4 ounces sulphur	45.2	2.0	2.5
11	H_3PO_4—4 ounces sulphur	18.1	3.4	0.0

In preparing the Iowa peat as a potting medium for these treatments, sulphur was added to each lot of 25 pounds of preacidified peat in the amounts indicated in Table V. It may be possible that the addition of sulphur in the proportion of 2 ounces to 25 pounds of Iowa peat preacidified with H_3PO_4 produces better results than H_3PO_4 without sulphur. The addition of sulphur did not seem to improve the potting medium when H_2SO_4 was used to adjust the pH.

Fertilizer 1 in Table VI consisted of 1 ounce ammonium sulfate, 1 ounce ferrous sulfate and 1 ounce monopotassium phosphate in 5 gallons of water. Fertilizer 2 was made by dissolving 1½ ounces of aluminum sulfate and 1½ ounces ferrous sulfate in 5 gallons of water. The results secured in treatments 12, 13, 16 and 17 indicate signifi-

TABLE VI—COMPARISON OF EFFECTS OF NUTRIENT SOLUTIONS ON ACID PEAT AND IOWA PEAT

Treatment Number	Treatment	Average No. Flowers Per Plant	Average Foliage Color Score	Average Score Plant Quality
12	Acid peat—fertilizer 1	45.2	4.7	5.0
13	Iowa peat—fertilizer 1	68.9	0.8	1.0
14	Iowa peat H_2SO_4 to pH 5.0—fertilizer 1	74.0	2.9	3.0
15	Iowa Peat H_3PO_4 to pH 5.0—fertilizer 1	44.9	2.5	2.5
16	Acid peat—fertilizer 2	64.1	4.9	4.5
17	Iowa peat—fertilizer 2	52.6	3.0	2.75
18	Iowa peat H_2SO_4 to pH 5.0—fertilizer 2	51.3	4.4	3.75
19	Iowa peat. H_3PO_4 to pH 5.0—fertilizer 2	41.9	3.6	3.25

cantly different reactions from the two fertilizers when used on the different peat soils. Fertilizer 1 gave better results on Iowa peat and fertilizer 2 seemed to be better adapted for use on acid peat. Both fertilizers definitely benefitted the Iowa peat which is naturally somewhat deficient in essential elements.

In treatments 14, 15, 18 and 19, these fertilizers were applied to Iowa peat which had been adjusted to pH 5 by acid applications. Again fertilizer 1 was superior to 2 in the number of blooms per plant and in color of foliage.

TABLE VII—COMPARISON OF WATERING WITH WATER ACIDIFIED WITH H_2SO_4 AND H_3Po_4

Treatment Number	Treatment	Average No. Flowers Per Plant	Average Foliage Color Score	Average Score Plant Quality
20	Acid peat with H_2SO_4 acidified water to pH 4.0	61.9	4.7	4.5
21	Same. pH 5.0	53.4	4.8	4.5
22	Acid peat with H_3PO_4 acidified water pH 4.0	61.6	3.2	3.75
23	Same. pH 5.0	63.9	4.4	4.0
24	Iowa peat with H_2SO_4 acidified water pH 4.0	54.0	3.4	3.5
25	Same pH 5.0	57.9	3.0	3.25
26	Iowa peat with H_3PO_4 acidified water pH 4.0	42.9	2.0	1.75
27	Same pH 5.0	39.5	2.0	2.25

No significant differences resulted in watering acid (Minnesota) peat With H_2SO_4 or H_3PO_4 acidified water. However, on Iowa peat H_2SO_4 acidified water gave highly significant differences when compared with H_3PO_4 acidified water. It is possible that these differences between treatments can be attributed to the fact that H_2Po_4 has tied up the iron and other essential elements in the soil and made them less available to the plants.

SUMMARY

This paper is a report of 15 months work, with the Kurume azalea var. Coral Bells and this plant's response to various soil acidifying techniques. The principal findings include:

1. Acid (Minnesota) sphagnum moss peat of pH 4.5 produced significantly better plants than Iowa hypnum moss peat of pH 5.5. On the basis of number of flowers produced per plant, color of foliage and plant quality, Iowa peat, acidified with H_2SO_4 and fertilized with 1

ounce ammonium sulfate, 1 ounce ferrous sulfate and 1 ounce monopotassium phosphate in 5 gallons of water, produced better plants than other treatments used on this potting medium. Other treatments of Iowa peat also showed considerable improvement over the check, but none of them were equal in performance to acid (Minnesota) peat. Under the conditions of this experiment, Iowa peat cannot be made as satisfactory as acid peat for azalea culture.

2. H_2SO_4 when used on Iowa peat for adjusting pH is definitely superior to H_3PO_4.

3. A fertilizer containing monopotassium phosphate, ammonium sulphate and ferrous sulphate produced better results on Iowa peat than a fertilizer of aluminum sulphate and ferrous sulphate.

4. Acidified water maintained a low pH in both Iowa and acid (Minnesota) peat. The use of acidified water on acid peat did not increase the number of flowers per plant. There was no significant difference in the results from watering acid peat with H_2SO_4 or H_3PO_4 acidified water but on Iowa (hypnum) peat H_2SO_4 was far superior to H_3PO_4.

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The Effects of Certain Fertilizers and Potting Media on the Growth and Flowering of Azaleas[1]

By J. Foret and E. C. Volz, *Iowa State College, Ames, Ia.*

In previous work with the culture of acid-tolerant plants under Iowa conditions, Ballhorn (2), found that acid sphagnum peat was a better medium for the growth and flowering of azaleas than Iowa hypnum peat (an alkaline peat). The water available to most greenhouse operators is known as "hard water", and contains calcium and magnesium in such quantities as to be detrimental to the best soil conditions for the optimum growth of azaleas.

In view of the fact that two limiting factors, water and soil, might influence the culture of acid-tolerant plants in Iowa, rainwater was used as a soil moisture supply in this experiment to permit a more exacting study of the effects of fertilizers and potting media.

Disturbances in iron nutrition are probably the most recognized disorders causing chlorosis in azaleas. It is not the actual soil acidity which benefits these plants most, but rather the amount of iron and other elements which become available as the soil acidity increases (lowering the pH) (1, 4, 8). Iron is utilized by the plant in the production of the enzyme catalase (3), as a part of the enzyme peroxidase, which functions as an oxidizing enzyme in oxygen transfers in respiration (5), and plays an important role, either direct or indirect in the synthesis of chlorophyll in green plants. Iron may be rendered unavailable to plants growing in soil or water cultures by reacting with phosphorus when the acidity increases below pH 5 (4, 6).

The state of iron in the plant tissues may also influence its utilization by the plant. Weiss (7), found that considerable quantities of iron may be present in the tissues of plants which exhibit symptoms of iron deficiency or chlorosis. On the other hand, if the soil acidity is too high (low pH) toxicities of aluminum, and so on may develop.

Materials and Methods

The Kurume type azalea, variety Snow, was obtained as rooted cuttings December 10, 1946, and potted in 2½-inch pots. A sufficient quantity of cuttings was ordered to permit a selection of uniform cuttings for the experiment.

The most readily available and suitable local mineral and organic soils were used as potting media. Two types of peat were used as potting media for some treatments; acid sphagnum peat from a Minnesota source with pH 5.50, and an Iowa hypnum peat with pH 6.95. Compost and oak-leaf mold from local sources were used alone, and in combination with the acid peat, as potting media for other treatments. Potting media used and fertilizers applied are shown in Table I.

Block arrangements were made on December 12, and the plants placed in a 60-degree house. On June 14, 1947, the plants were shifted to 4-inch pots and moved to a well-shaded greenhouse.

[1]Journal Paper No. J–1511 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 926.

TABLE I—CULTURAL PRACTICES

Treatment Number	Potting Media	Fertilizer Applied
1	Iowa peat	None
2	Iowa peat	Vigoro; ¼ lb per square yard every 6 weeks from May to August.
3	Iowa peat	$Al_2(SO_4)_3$, Fe SO_4(1½ oz each in 5 gal H_2O), applied every 6 weeks.
4	Iowa peat	$(NH_4)_2SO_4$, $Al_2(SO_4)_3$, Fe SO_4(1 oz each in 5 gal H_2O); applied every 6 weeks.
5	Iowa peat	KH_2PO_4(5 gms), S (2 gms) per lb peat at potting time.
6	Acid peat	None
7	Acid peat	Same as No. 2.
8	Acid peat	Same as No. 3.
9	Acid peat	Same as No. 4.
10	Acid peat	Same as No. 5.
11	Oak-leaf mold	None.
12	One-half compost, one-quarter acid peat, one-quarter oak-leaf mold (by volume)	None.
13	Same as No. 12	Same as No. 4.
14	Same as No. 12	S, $FeSO_4$, $Al_2(SO_4)_3$ (equal parts), 4 gms mixture per lb potting media.
15	Acid peat	Same as No. 14.
16	Acid peat	Same as No. 14 plus Vigoro applied as in No. 2.
17	Acid peat	7 gms 6-8-4 per lb peat at potting time.
18	Acid peat	Same as 17, plus Vigoro.
19	Acid peat	KH_2PO_4(5 gms), Mg SO_4(7 gms) per lb peat at potting time.
20	Compost	Same as No. 19.
21	Acid peat	7 gms 6-8-8 per lb peat at potting time.
22	Acid peat	7 gms 6-8-16 per lb peat at potting time.
23	Acid peat	KH_2PO_4 (10 gms) dried blood (6.4 gms) per lb peat at potting time.
24	Acid peat	Liqua Vita 1/250 applied every 10 days during spring, dried blood (6.4 gms) per lb peat at potting time.
25	Acid peat	Standard 4-12-4, applied as fertilizer as in No. 2.

All vegetative growth was regularly soft-pinched to 3 inches to promote branching. No pinching was done after June 15th to allow time for the new shoots to develop sufficiently before flower bud initiation took place. Syringing was done with lawn sprinklers installed in the greenhouse. On August 1st, all shading was removed from the roof of the greenhouse to harden vegetative growth and hasten flower bud development.

There was a total of 25 treatments, six replications per treatment and two plants per replication. The arrangement used was a lattice square.

Data collected included pH of the media June 15th and October 10, foliage color, number of flower buds produced, and plant quality. pH determinations were made with a Coleman glass electrode pH meter. Ten milliliter samples of air dried media were mixed with an equal volume of distilled water, stirred, and allowed to stand ½ hour, and the solution decanted off for the determination. The color of the foliage was used as an index of nutritional iron disorders. The foliage color scores were so graduated that a score of 5 signified a plant with normal, dark green foliage, and so down to a score of 1 which indicated a plant with extremely chlorotic leaves. The number of flower buds produced on the plants served as an indication of the general response of the plant to fertilizers and potting media. Plant quality was based on vigor, color, size of leaves, and size of plants. Each of the four points considered counted one point towards the score the plant was given.

Results and Discussion

The selection of uniform plants at the outset of this study was instrumental in reducing the amount of variation within treatments, as substantiated by the fact that although the experiment was originally designed as a lattice square experiment with (k + 1) replicates, a preliminary analysis of variance showed that there was very little variation within treatments and the efficiency of this method of analysis was no better than that of a randomized complete blocks design. As a result, all data were analyzed by the latter method.

Treatment 23 (acid peat; KH_2Po_4, dried blood) was used as the check in this study, since it is the treatment employed by a local commercial greenhouse operator with considerable success. All references to significance in the discussion of treatment means are based on the mean of this check treatment.

Only the mean pH readings taken October 10 will be considered in the discussion of the final effect on the plants, since there were no significant differences between readings taken on the two dates. The readings taken June 14th served as a check against any unexpected changes which might have occurred during the course of the experiment.

Nearly all the plants in treatments 11, 12, 14, and all the plants in treatment 20, grown in organic and mineral soils from local sources, died during the course of the experiment as a result of the treatment effects.

Treatments 1 and 6 represent azaleas grown on two types of natural occurring peat soils without the addition of fertilizers. Foliage color scores of these two treatments reveal the plants were able to absorb and utilize sufficient iron to maintain almost the same leaf color in the vegetative growth made. The larger number of flower buds produced by treatment 6 (Table II) is indicative that the acid sphagnum peat had a better balance of the essential mineral elements than did the Iowa, hypnum peat.

The pH readings of the potting media of treatments 2 (Iowa peat; Vigoro) and 7 (acid peat; Vigoro) were significantly different. It might be well to note that the addition of Vigoro increased the pH of treatment 2 over that of treatment 1 and decreased the pH of treatment 7 below that of treatment 6; although neither variation was significant. The addition of Vigoro resulted in a lower foliage color score than was obtained with the unfertilized Iowa peat. The fertilizer effect might be explained in that the amount of available iron in Iowa peat is low and that the addition of phosphorus (in Vigoro) aggravated the condition by reacting with the iron compounds present to render them insoluble or unavailable to the plant, or both. The foliage color score of treatment 7 was significantly better than that of treatment 2; but was identical to the score of treatment 6 (acid peat; untreated), indicating that iron rendered unavailable by the phosphorus comprised that portion in excess of that required by the plant to maintain an almost normal green color. Treatment 2 produced twice as many flower buds as did treatment 1, conversely, very little increase was noted when comparing treatments 6 and 7 (Table II).

TABLE II—Results of Treatments

Treatment No.	pH Jun 14	pH Oct 10	Foliage Color Score	No. Flower Buds Produced	Plant Quality Score
1	6.95	6.94	3.58	5.5	1.00
2	6.55	7.16	2.80	10.5	1.25
3	6.35	6.92	4.33	6.1	1.00
4	5.60	6.72	4.50	20.4	2.08
5	5.90	5.96	3.91	18.8	2.66
6	5.10	5.36	4.00	25.6	2.91
7	4.91	5.26	4.00	27.3	3.24
8	4.68	4.88	5.00	23.4	3.83
9	4.76	5.01	4.00	25.7	3.61
10	4.38	3.96	3.91	18.8	2.66
11	7.38	7.21	0.33	0.0	0.00
12	7.08	7.33	0.66	0.5	0.00
13	6.26	6.93	3.16	18.1	2.00
14	6.98	6.59	1.16	3.6	0.25
15	4.91	4.33	3.58	22.8	3.25
16	4.71	4.44	4.25	31.6	3.25
17	4.91	5.40	4.41	24.0	3.41
18	4.68	5.28	4.33	23.7	2.91
19	5.03	5.47	3.25	19.1	2.83
20	7.30	6.91	0.00	0.0	0.00
21	5.71	5.19	3.91	20.9	2.91
22	5.18	5.00	4.25	20.3	3.08
23	5.33	5.57	3.83	25.6	3.08
24	5.41	5.38	3.91	23.5	2.83
25	5.46	5.35	4.16	21.4	3.33

*Each value is a mean of 12 readings.
Difference required for significance:

	5 Per Cent Level	1 Per Cent Level
pH Jun 14....	0.34	0.45
pH Oct 10.....	0.207	0.225
Foliage color..	0.57	0.75
Flower buds...	5.09	6.73
Plant quality	0.66	0.87

The pH of treatment 3 (Iowa peat; $Al_2(SO_4)_3$, $FeSO_4$) did not vary significantly from that of treatment 1 (Iowa peat; untreated) yet the foliage color scores reveal that treatment 3 was significantly better than treatment 1. The fertilizers applied to treatments 3 and 8 supplied iron in an inorganic form, which form was either immediately available or rendered available to the plants in another form in large enough quantities to maintain excellent foliage color (particularly in treatment 8). Data in Table II show that treatment 8 produced nearly four times as many flower buds as did treatment 3, but did not vary significantly from the check. Treatment 8 was the only treatment in the experiment which had a plant quality score that was significantly larger than that of the check.

Data on foliage color in Table II show that treatment 4 received the best score of all plants grown on Iowa peat. It might be said that the problems of iron absorption and utilization of plants grown in this media were most nearly met in this treatment. Fertilization of the plants in treatments 4 and 9 was with a mixture of compounds, each of which was a sulfate probably induced base exchange reactions in the media which released iron in a readily available form.

Table II reveals that the mean pH of treatment 5 (Iowa peat; KH_2PO_4, sulphur) was much higher than that of treatment 10 (acid peat; KH_2PO_4, sulphur) and that both differed significantly from the experimental check; the former being greater and the latter, less. Treatment 5 was grown in a media which is probably low in available iron and was supplied with a source of phosphorus with which the iron

reacted. Sulphur was also supplied and tended to acidify the soil and intensify this reaction, leaving less iron available to the plant in proportion to the amount of vegetative growth made. In treatment 10, soil acidity was increased beyond the point of tolerance of the Kurume azalea (about pH 4.0) by the addition of sulphur; and the phosphorus supplied reacted with the available iron to render both unavailable.

Since the fertilizers used in both treatments 7 and 25 were basically 4–12–4 mixtures, an increase in flower bud production in treatment 7 might be attributed to the essential minor and trace plant food elements contained in Vigoro (treatment 7).

Data presented in Table II show that the foliage color score of treatment 13 was significantly better than treatments 11, 12, and 14, and that, as a whole, this was the poorest series in the study. The potting media for this series came from a local source, hence the high pH values indicating a high lime condition. Application of an acid-forming liquid fertilizer in treatment 13 did not lower the pH of the medium below that of treatment 14, but plants in the former treatment had a much better foliage color score. Watering the plants in treatment 13 every 6 weeks with a liquid fertilizer provided a constant source of iron, which probably accounts for the better foliage color score of this treatment over that of treatment 14, to which $FeSO_4$ was added only at potting time. The $(NH_4)_2SO_4$ applied to treatment 13 is more than likely responsible for the larger number of flower buds produced; the higher plant quality score, to the combined effect of the $FeSO_4$ and $(NH_4)_2SO_4$.

Treatment 16 produced significantly more flower buds than treatment 15 and the check. These differences might be accounted for by the fact that a better nutritional balance existed in the medium of treatment 16 because of the minor elements supplied by Vigoro. This was the only treatment (treatment 16) in the experiment which produced significantly more flower buds than did the experimental check treatment.

Doubling and quadrupling the potassium content of the 6–8–4 fertilizer (treatment 17) in treatments 21 and 22 failed to show any results.

The highly significant value obtained as a result of an analysis of covariance signified that the pH of the potting medium and the foliage color of azaleas in this experiment were independent of one another. This implies that the mean pH of the medium in which plants in a specific treatment are growing might be near the neutral point, yet the mean foliage color score for this same treatment will be high; while plants receiving another treatment and growing in the same media as the first group might have an almost identical pH, the foliage color score of plants in the second treatment will be comparatively lower (Table II; treatments 2 and 1, 16 and 15). On the other hand, the pH of the medium might be low and the foliage color score low, and another treatment in the same medium might have a comparatively higher pH reading and a higher foliage color score (Table II; treatments 8 and 10, 17 and 21).

The fact that the soil acidity is high (low pH) does not always im-

ply that iron, the deficiency of which generally causes chlorosis in azaleas, is in a readily available form, or that if available, will be utilized by the plant for the formation of chlorophyll. Conversely, a high pH does not always mean that an azalea will be chlorotic; or that azaleas growing in what was known to be an alkaline soil before fertilizer was added, would be chlorotic if the pH of the medium remained near the neutral point (treatment 13).

SUMMARY

Most plants grown in acid peat were significantly better than those receiving the same treatment and grown in an alkaline Iowa peat; and substantiates the findings of Ballhorn (2). From the standpoint of flower bud production, a mixture of sulphur, $FeSO_4$, $Al_2(SO_4)_3$, and Vigoro, was a better fertilizer for azaleas than KH_2PO_4 and dried blood. Phosphorus, in sufficient quantities in the soil, will react with iron to render the iron unavailable and cause chlorosis of azaleas. Maintaining a high soil acidity (pH 4.0) proved deleterious to the azalea by causing stunting and chlorosis. It was possible to maintain fairly good foliage color on azaleas grown in a mixture of Webster soil, acid peat, and locally obtained oak-leaf mold. Doubling and quadrupling the potassium content of a 6–8–4 fertilizer has no effect of the foliage color and quality of azaleas so treated. The foliage color of azaleas and pH of the medium in which they were grown were independent of one another.

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Rooting Evergreen Cuttings with Hormones[1]

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THE value of certain plant hormones in rooting cuttings of many kinds of plants has been established by extensive research and their use has been widely adopted by plant propagators. There is insufficient evidence, however, as to the value of hormone treatment for certain plant species and there is need for further study of methods of hormone application. Among the species that have not been tested sufficiently are many of the evergreens.

Of the substances that promote rooting, indolebutyric and naphthaleneacetic acids have been most widely recommended. The first preparations that became available to commercial propagators were stock solutions of indolebutyric acid (Hormodin A) and powder preparations of naphthaleneacetic acid (Rootone). Hitchcock and Zimmerman (1) had found these hormones effective with cuttings of many plant species, especially when the temperature of the propagating medium was maintained at 70 degrees F (2).

At first, the 24-hour solution-immersion method of hormone application was recommended. More recently, favorable results obtained with hormones in the form of dry powders have resulted in the almost universal adoption of this simpler method. In some areas, at least, hormone solutions are no longer available.

Experiments with evergreen species that are extensively propagated in western Washington were begun at the Western Washington Experiment Station in 1940. Evidence of the value of hormones in propagating evergreens had been published previously, including a review by Kirkpatrick (3) of experiments in which cuttings of many species, both broad-leaved and coniferous, showed favorable responses to indolebutyric acid solutions and powders. Because this hormone was available to propagators of western Washington and had been tried by many of them with unfavorable results, it was tested in the form of solutions at various concentrations and later was compared with naphthaleneacetic acid solutions and certain powder preparations.

MATERIALS AND METHODS

From the many species of evergreen trees and shrubs that are propagated in western Washington, certain ones were selected[2] as representative of several important groups such as the arborvitae, cypresses, hollies, junipers, yews, and so on. In all, 35 species were used in the course of the experiments.

Cuttings were obtained in late October and early November. They

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[2]Grateful acknowledgment is made of the generous cooperation of Bonnell Nurseries, Inc., Renton, Washington, and the Metropolitan Park Board of Tacoma in supplying many of the cuttings.

were made from terminal portions of vigorous side branches and consisted of the current season's growth. Cuttings 4 to 6 inches in length were used, those of each species being fairly uniform in length. Leaves were removed from the basal ½ to ⅔ of each cutting.

The cuttings for each experiment were obtained one day and held overnight in damp burlap in cool outdoor conditions. The following day they were prepared and 24-hour chemical treatments were started in a well-ventilated basement room held constantly at 68 degrees F.

Indolebutyric acid and naphthaleneacetic acid were obtained in chemically pure, crystalline form. In making solutions of these chemicals, the desired quantity was first dissolved in 95 per cent alcohol, which was then diluted with tap water to the desired strength.

Two commercially available powder preparations were obtained under the trade names "Stimroot" and "Rootone". The former was reported[8] to contain 2 milligrams of indolebutyric acid per gram of talc. The latter was reported to contain alphanaphthylacetamide.

Powder preparations of indolebutyric acid were made by first dissolving the pure crystals in acetone and then mixing this solution in talc to form a thin paste. This paste was then allowed to dry, after which it was ground to powder in a hand mortar.

Solution treatments were applied to cuttings by standing them in the solution to a depth of about 1 inch in glass beakers or earthenware crocks for 24 hours, after which the cuttings were removed, immediately rinsed with tap water and inserted in the propagating frame. Cuttings treated with chemical solutions were always compared with others treated for the same time with water only. Powder preparations were applied by dipping the basal ends of the cuttings into the powder to a depth of ½ inch, after which the cuttings were tapped lightly to remove excess powder. The cuttings were slightly damp when dipped, so that the powder clung to them in a thin layer.

Throughout the experiments, examination of all cuttings of a species was made as soon as any treatment had resulted in satisfactory root systems on a majority of the cuttings treated. This was done to determine the relative effects of the various treatments on the rate of root formation. It is possible that many cuttings that failed to root would have done so if they had been allowed to remain in the frame for a sufficient length of time. It was felt, however, that the rate of rooting should be used as one criterion of the effectiveness of the treatments, because rapid rooting is always desirable in commercial propagation. The data were obtained, therefore, at a relatively early stage of root development, when the effectiveness of the treatments used could be judged in terms of earliness of rooting, the percentage of cuttings forming roots in a relatively short time, and the desirability of the root systems that were developing.

Bottom heat under the propagating medium was used throughout the experiments because this is an established practice in the propagation of evergreens in the fall and winter months.

[8]From correspondence with Dr. A. E. Hitchcock, Boyce Thompson Institute for Plant Research, Yonkers, New York.

Equipment

The experiments reported herein were carried on in an unheated lathhouse roofed with hotbed sash to protect the propagating frames from heavy winter rains. The frames, of concrete construction, were divided into 3- by 6-foot sections, each covered with a standard hotbed sash and equipped with electric heating cables for bottom heat, under thermostatic control. Except during rare cold spells, the temperature of the propagating medium was maintained at 70 degrees F, but air temperatures were uncontrolled.

Experiments

In preliminary experiments in 1940 and 1941 it was found that indolebutyric acid solutions produced maximum rooting response, with a majority of the 17 species tested, when a concentration of 60 to 80 parts of the acid per million parts of water was used. Sand and sand-peat were equally satisfactory media except for *Calluna vulgaris* and *Camellia japonica*, which gave much better results in sand-peat than in sand. These experiments also showed that the desired temperature of the medium could not be maintained constantly in the concrete frame. Consequently, the walls were insulated with 2-inch boards before the next experiment was started.

The experiments of 1942 employed cuttings of 24 species which were rooted in sand and sand-peat after treatment with indolebutyric acid solutions at concentration of 40, 60, 80 and 100 parts per million. The results are shown in Tables I and II.

TABLE I—Cuttings Taken November 11 to 23, 1942, Treated with Indolebutyric Acid Solutions for 24 Mours, Rooted in Sand with 70 Degrees Bottom Heat (25 Cuttings Each Lot)

Species*	Days** to Root	Treatment and Per Cent Rooted (Ppm)				
		Water (Check)	40†	60	80	100
Buxus sempervirens	56	24	92	96	96	92
Camellia japonica	61	20	68	72	76	60
Cephalotaxus drupacea	67	24	88	100	96	96
Cephalotaxus Fortuni	75	20	92	100	100	100
Chamaecyparis erecta viridis	90	16	88	100	100	100
Chamaecyparis filifera	76	8	88	96	84	80
Chamaecyparis nidiformis	78	8	88	100	100	100
Chamaecyparis plumosa aurea	65	48	96	100	96	96
Chamaecyparis obtusa	73	8	80	92	92	96
Chamaecyparis wisseli	95	4	88	100	100	100
Ilex Aquifolium	54	0	60	56	40	40
Ilex myrtifolia	50	0	92	96	92	92
Ilex Pernyi	54	0	92	100	100	100
Juniperus hibernica	67	48	88	92	92	100
Juniperus Sabina	99	24	88	92	92	84
Juniperus sylvestris	67	0	88	100	100	100
Taxus baccata	98	0	72	80	84	80
Taxus baccata aurea	92	8	80	92	88	88
Thuja pyramidalis	72	8	92	100	100	92
Thuja spiralis	72	16	88	100	100	100
Thuja Woodwardii	62	0	96	100	96	80
Thujopsis dolabrata	71	56	100	100	100	100

*The nomenclature used is that of Rehder (7).

**Number of days from insertion of cuttings until the most successful treatments had resulted in good root systems consisting of several strong roots, 2 to 3 inches in length.

†Concentration of solution expressed as parts of the acid to one million parts water.

TABLE II—CUTTINGS TAKEN NOVEMBER 11 TO 23, 1942, TREATED WITH INDOLEBUTYRIC ACID SOLUTIONS FOR 24 HOURS, ROOTED IN SAND-PEAT WITH 70 DEGREES F BOTTOM HEAT (25 CUTTINGS EACH LOT)

Species	Days to Root	Treatment and Per Cent Rooted (Ppm)				
		Water (Check)	40	60	80	100
Buxus sempervirens	56	32	88	88	84	80
Camellia japonica	61	16	84	96	100	92
Cephalotaxus drupacea	67	20	84	100	92	88
Cephalotaxus Fortuni	75	24	88	92	92	88
Chamaecyparis erecta viridis	90	20	92	100	100	100
Chamaecyparis filifera	76	4	80	96	92	92
Chamaecyparis nidiformis	78	28	100	100	100	100
Chamaecyparis plumosa aurea	65	40	80	88	80	80
Chamaecyparis obtusa	73	20	92	96	100	96
Chamaecyparis wisseli	95	12	80	100	100	100
Daphne odora	40	16	100	100	—	—
Ilex Aquifolium	54	0	100	100	80	70
Ilex myrtifolia	50	0	100	100	96	92
Ilex Pernyi	54	0	92	100	100	100
Juniperus hibernica	67	28	60	56	64	68
Juniperus Sabina	99	16	80	92	88	88
Juniperus sylvestria	67	4	88	92	92	88
Pieris japonica	70	24	100	100	—	—
Taxus baccata	98	4	84	92	100	92
Taxus baccata aurea	92	12	92	96	100	100
Thuja pryamidalis	72	16	84	92	92	80
Thuja spiralis	72	28	92	100	100	80
Thuja Woodwardii	62	0	92	100	100	84
Thujopsis dolabrata	71	36	100	100	100	100

The data in Tables I and II show that all concentrations of indolebutyric acid used in 1942 accelerated rooting. One or more treatments resulted in 100 per cent rooting of 21 of the 24 species, and all species rooted at least 92 per cent with suitable treatment. The number of days required for formation of good root systems varied from 40 with *Daphne odora* to 99 for *Juniperus Sabina.*

A majority of the species rooted equally well in the two media. *Camellia japonica* and *Ilex Aquifolium* responded better in sand-peat. *Taxus baccata* also rooted somewhat better in this medium than in sand. Sand gave better results with *Chamaecyparis plumosa aurea* and *Juniperus hibernica*[4] and slightly better results with a few other species.

A majority of the 24 species rooted best when the solution concentration was 60 parts per million but the results were practically the same for 80 parts per million. A concentration of 40 parts per million gave equally good results with several species, especially in the sand-peat medium. The results indicate that solution concentrations between 60 and 80 parts per million are satisfactory for all the species tested. These results are in close agreement with those reported by Kirkpatrick (3) for many species of coniferous and broad-leaved evergreens.

Besides the differences in percentages of cuttings that rooted following treatment with the hormone at the different concentrations, significant differences were also noted in the appearance of the root systems. In general, treatment with 60 parts per million resulted in the most

[4]The superiority of sand as a medium for *Juniperus hibernica* has been noted by Laurie and Chadwick, p. 197 (4).

desirable root systems, that is, a few long, strong, well-balanced roots. The higher concentrations usually resulted in more roots per cutting, but with some species these roots were short, close together and brittle. The lower concentrations, such as 40 parts per million, often resulted in only one or two long roots per cutting. Typical responses of four species to treatment with indolebutyric acid solutions are shown in Fig. 1.

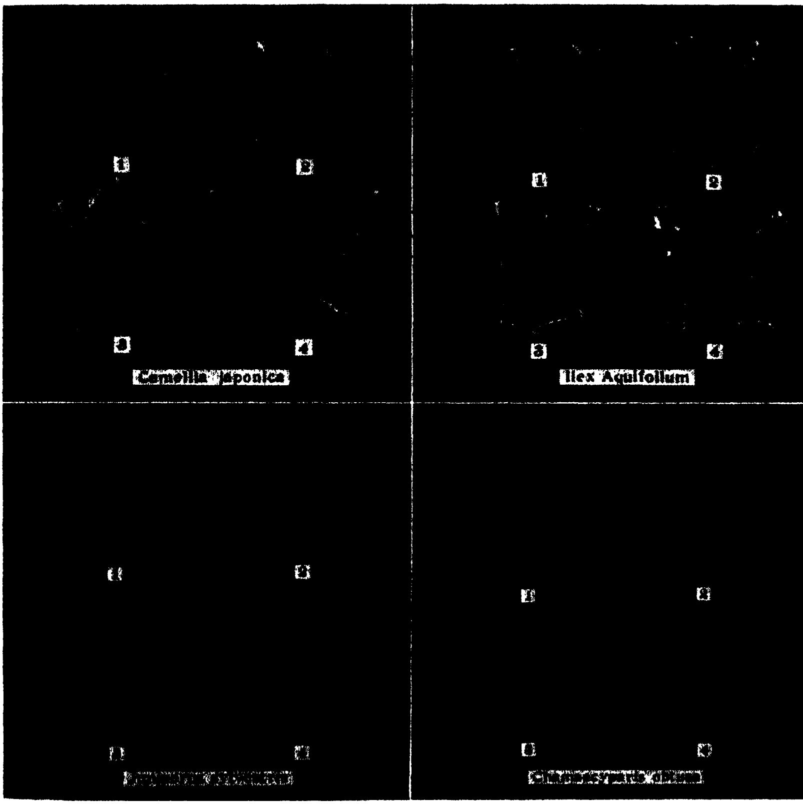

FIG. 1. Evergreen cuttings taken in November, treated for 24 hours in water solutions of indolebutyric acid at the following concentrations: (1) water only; (2) 40 parts per million; (3) 60 parts per million; (4) 80 parts per million. Rooting response after 54 to 73 days in propagating bench.

Because of the growing popularity of the powder-dip method, another experiment was set up in 1944 to compare this method with solution treatments. Suitable cuttings of 12 species of evergreens were obtained from metropolitan parks of Tacoma and from the grounds of the Western Washington Experiment Station. Seven species were rooted in sand and 11 were rooted in sand-peat. Two powder preparations, Stimroot and Rootone were tested in comparison with indolebutyric acid solutions at concentrations of 60 and 80 parts per million.

In this experiment the number and length of roots per cutting, as well as percentages rooted, were recorded. The results of this experiment are shown in Tables III and IV.

TABLE III—CUTTINGS TAKEN NOVEMBER 3 TO 15, 1944, TREATED WITH CHEMICAL POWDERS AND SOLUTIONS, ROOTED IN SAND WITH 70 DEGREES F BOTTOM HEAT (50 CUTTINGS EACH LOT)

Species	Days to Root	Rooting Response*	Water (Check)	Stimroot (Powder)	Rootone (Powder)	Indolebutyric Acid Solutions	
						60 Ppm	80 Ppm
Chamaecyparis erecta viridis	88	Per cent	16.0	64.0	48.0	92.0	100.0
		Number	1.4	5.2	1.5	9.6	9.8
		Length	1.9	2.9	2.4	2.8	2.6
Chamaecyparis nidiformis	91	Per cent	36.0	88.0	80.0	92.0	92.0
		Number	1.5	4.6	4.0	6.8	7.5
		Length	2,5	2.2	2.6	2.2	2.3
Chamaecyparis plumosa aurea	65	Per cent	64.0	84.0	76.0	96.0	88.0
		Number	4.0	6.0	5.7	13.0	16.0
		Length	2.0	2.4	2.0	2.0	1.5
Juniperus Sabina	101	Per cent	36.0	60.0	52.0	76.0	88.0
		Number	1.3	4.0	3.4	9.0	8.5
		Length	3.0	3.2	3.0	2.6	3.0
Juniperus tamariscifolia.....	108	Per cent	30.0	72.0	64.0	88.0	80.0
		Number	1.6	5.0	2.6	6.8	5.9
		Length	2.0	2.5	1.7	2.7	2.4
Taxus baccata stricta	105	Per cent	0.0	86.0	60.0	90.0	94.0
		Number	—	2.4	2.3	2.3	2.4
		Length	—	2.6	2.6	3.5	3.4
Thuja pyramidalis	73	Per cent	28.0	68.0	64.0	100.0	100.0
		Number	1.4	5.4	4.5	8.8	13.1
		Length	1.5	1.8	1.7	1.9	1.9

*Respectively, per cent of cuttings rooted, average number of roots per cutting, average length of roots in inches as shown in lines to the right.

Tables III and IV show that, in general, solutions of indolebutyric acid produced higher percentages of rooted cuttings or more roots per cutting, or both, than were obtained with either of the powders, Stimroot and Rootone. The larger number of roots developed with indolebutyric acid solution treatments, with all species but one, is especially noticeable. The powders stimulated rooting in comparison with untreated cuttings of all species except two. *Ilex Aquifolium* failed to root, and *Camellia japonica* and *Pieris japonica* rooted poorly following powder treatments, whereas all three rooted well after treatment with indolebutyric acid solutions. *Skimmia japonica* rooted well without chemical treatment and 100 per cent with all chemical treatments.

Stimroot was more effective than Rootone with 8 of the 12 species. With species of *Chamaecyparis* and *Taxus,* good percentages of the cuttings formed roots after treatment with Stimroot, but in almost all cases, a smaller number of roots formed on each cutting in comparison with the results obtained with indolebutyric acid solutions. As in previous experiments, some differences were observed in rooting of the same species in the two media but the differences were not great.

This experiment showed that the two powders, Stimroot and Rootone, were less effective than the indolebutyric acid solutions, but raised the question whether indolebutyric acid in powder form would be as

TABLE IV—CUTTINGS TAKEN NOVEMBER 3 TO 15, 1944, TREATED WITH CHEMICAL POWDERS AND SOLUTIONS, ROOTED IN SAND-PEAT WITH 70 DEGREES F BOTTOM HEAT (50 CUTTINGS EACH LOT)

Species	Days to Root	Rooting Response	Water (Check)	Stimroot (Powder)	Rootone (Powder)	Indolebutyric Acid Solutions	
						60 Ppm	80 Ppm
Camellia japonica	69	Per cent	16.0	12.0	8.0	88.0	100.0
		Number	1.5	2.0	1.0	11.6	13.3
		Length	0.6	2.5	1.0	3.4	3.9
Chamaecyparis erecta viridis	88	Per cent	24.0	84.0	40.0	88.0	96.0
		Number	2.5	4.0	2.5	6.8	8.4
		Length	1.9	2.8	2.6	2.6	2.9
Chamaecyparis nidiformis	85	Per cent	20.0	96.0	76.0	100.0	96.0
		Number	1.8	6.2	4.6	9.8	13.0
		Length	1.8	3.2	3.4	3.0	3.0
Chamaecyparis plumosa aurea	65	Per cent	56.0	76.0	64.0	92.0	88.0
		Number	3.5	5.5	6.0	15.0	17.5
		Length	1.5	2.0	2.0	2.0	1.5
Ilex Aquifolium	60	Per cent	0	0	0	92.0	96.0*
		Number	0	0	0	9.7	9.0
		Length	0	0	0	3.8	4.0
Juniperus Sabina	101	Per cent	44.0	60.0	64.0	80.0	92.0
		Number	4.2	5.3	3.0	8.8	9.5
		Length	2.4	2.4	2.8	2.7	2.7
Juniperus tamariscifolia	108	Per cent	20.0	64.0	40.0	76.0	92.0
		Number	3.0	6.0	3.0	7.4	7.3
		Length	2.0	2.0	2.0	2.0	2.2
Pieris japonica	69	Per cent	28.0	48.0	28.0	92.0	96.0
Skimmia japonica	48	Per cent	88.0	100.0	100.0	100.0	100.0*
		Number	3.3	5.0	4.6	17.9	17.3
		Length	2.3	3.0	3.0	2.5	2.5
Taxus baccata aurea	96	Per cent	12.0	88.0	56.0	88.0	96.0
		Number	1.0	1.8	1.5	2.5	3.0
		Length	2.0	3.8	3.5	3.5	3.0
Thuja pyramidalis	73	Per cent	12.0	72.0	60.0	92.0	96.0
		Number	1.3	3.6	2.3	6.0	9.8
		Length	1.0	2.3	1.9	2.0	2.3

*Treated with 40 ppm instead of 80 ppm.

effective as it was in solution and also whether the powder preparations contained optimum amounts of the hormones. Consequently, indolebutyric acid was prepared as a powder by mixing it with talc at three concentrations: 15, 30 and 45 milligrams per gram of talc, respectively. Because Stimroot, which contains naphthaleneacetic acid, had shown a root-stimulating effect in the previous experiment and because naphthaleneacetic acid had been used successfully elsewhere, this chemical was also employed in the form of solutions, both alone and in combinations with indolebutyric acid. In this experiment, conducted in 1945, six plant species were used. The results are shown in Table V.

The data in Table V show that indolebutyric acid solutions were more effective than indolebutyric acid powders and that these powders, at concentrations of 30 and 45 milligrams per gram, were more effective than Stimroot. From 92 to 100 per cent rooting, and maximum number and length of roots were obtained with indolebutyric solutions, 60 parts per million and 80 parts per million giving almost identical results. The only exception was the yew, which responded better to

TABLE V—CUTTINGS TAKEN NOVEMBER 4 TO 19, 1945, TREATED WITH CHEMICAL POWDERS AND SOLUTIONS, ROOTED IN SAND-PEAT WITH 70 DEGREES F BOTTOM HEAT (25 CUTTINGS EACH LOT)

Species	Days to Root	Rooting Response	Water (Check)	Stimroot (Powder)	Indolebutyric Acid (Powder)			Indolebutyric Acid (Solution)		Naphthaleneacetic Acid (Solution)		Indolebutyric×Naphthalene acetic Solution		
					15*	30	45	60	80	60	80	20+20	30+30	40+40**
Chamaecyparis erecta viridis	92	Per cent	12.0	44.0	24.0	48.0	64.0	100.0	100.0	92.0	80.0	100.0	100.0	100.0
		Number	2.0	2.1	2.0	2.0	3.2	12.0	13.2	8.3	9.0	11.8	10.6	9.8
		Length	1.0	2.8	1.3	2.6	2.4	3.5	3.6	2.1	2.0	3.0	3.1	3.3
Chamaecyparis obtusa aurea	87	Per cent	20.0	52.0	52.0	72.0	76.0	100.0	92.0	64.0	76.0	76.0	100.0	92.0
		Number	1.0	2.6	3.9	5.4	5.1	8.0	7.7	4.7	4.5	5.1	6.5	6.0
		Length	1.2	2.4	2.0	2.3	2.2	3.0	2.9	2.6	3.0	2.5	2.4	2.4
Ilex Aquifolium	54	Per cent	0.0	16.0	40.0	76.0	72.0	100.0	—	100.0	92.0	100.0	100.0	—
		Number	—	2.4	8.1	10.7	9.5	14.0	—	13.6	13.4	16.6	17.2	—
		Length	—	0.6	1.7	2.3	2.3	2.5	—	2.2	2.2	2.7	2.8	—
Juniperus tamariscifolia	101	Per cent	12.0	52.0	32.0	76.0	80.0	100.0	96.0	64.0	52.0	96.0	84.0	80.0
		Number	1.0	1.6	1.5	4.7	4.8	9.0	9.1	6.5	6.5	7.5	6.8	6.2
		Length	1.5	3.0	1.8	3.4	3.0	3.8	3.5	2.5	2.5	4.3	4.0	3.6
Taxus baccata aurea	94	Per cent	0.0	40.0	40.0	52.0	40.0	92.0	96.0	100.0	92.0	100.0	100.0	100.0
		Number	—	1.6	1.4	1.5	1.3	3.1	2.9	10.6	11.3	8.3	8.7	9.5
		Length	—	2.4	3.1	3.3	3.0	2.5	3.7	2.3	2.4	2.7	2.7	2.5
Thuja pryamidalis	66	Per cent	12.0	60.0	72.0	84.0	80.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
		Number	2.0	3.3	4.7	6.0	5.6	13.3	13.0	16.8	17.4	10.3	13.0	14.3
		Length	1.0	2.2	3.2	3.1	2.9	3.5	3.4	2.6	2.4	3.1	3.3	3.2

*15, 30 and 45 milligrams indolebutyric acid per gram talc, respectively.
**20 parts per million indolebutyric plus 20 parts per million naphthaleneacetic acid, and so on.

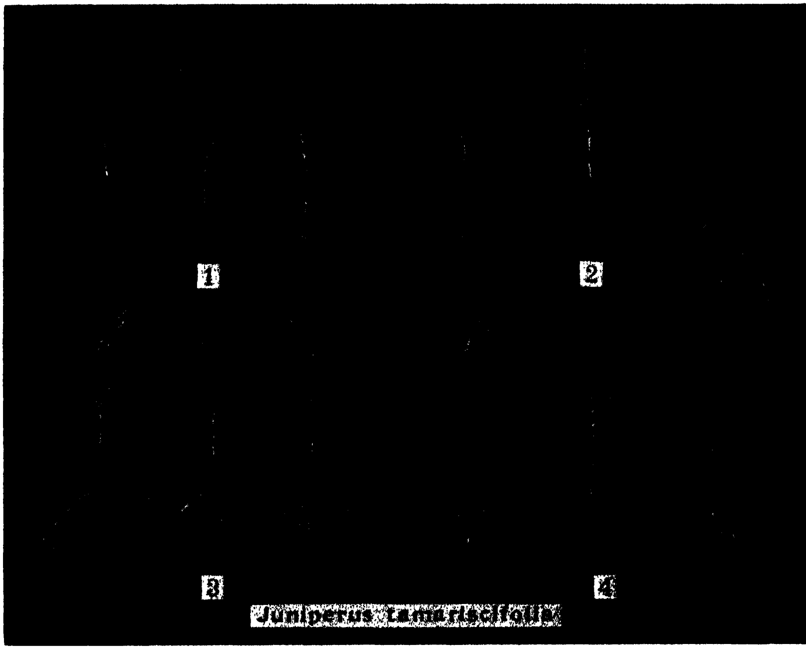

FIG. 2. Rootings of *Juniperus tamariscifolia* in 101 days. Treatments: (1) water only; (2) 60 parts per million indolebutyric acid (solution); (3) 20 parts per million indolebutyric plus 20 parts per million naphthaleneacetic acids (solution); (4) 30 milligrams indolebutyric acid per gram of talc (powder).

naphthaleneacetic acid. Fig. 2 shows typical responses of *Juniperus tamariscifolia* to indolebutyric solutions and powders, and to a combination of indolebutyric and naphthaleneacetic acids in solution. The responses of this species were fairly typical of the species used, excepting the yew. All of the powders stimulated rooting when compared with the water treatment. The optimum concentration of indolebutyric acid powder would seem to have been 30 milligrams per gram of talc as the 45 milligram concentration gave no significant increase in rooting except possibly with one species.

With the yew, naphthaleneacetic acid solutions were superior to indolebutyric acid solutions as shown by the greater number of roots produced per cutting. The combination of indolebutyric and naphthaleneacetic acids in solution did not prove to be superior to indolebutyric alone except with the yew, again indicating that naphthaleneacetic is more effective than indolebutyric with this species. Typical responses of the yew, showing superior results with naphthaleneacetic acid solutions, are illustrated in Fig. 3. With *Thuja pyramidalis*, naphthaleneacetic produced more but shorter and less desirable roots than those produced with indolebutyric acid.

Though not shown by the recorded data, it was observed that the

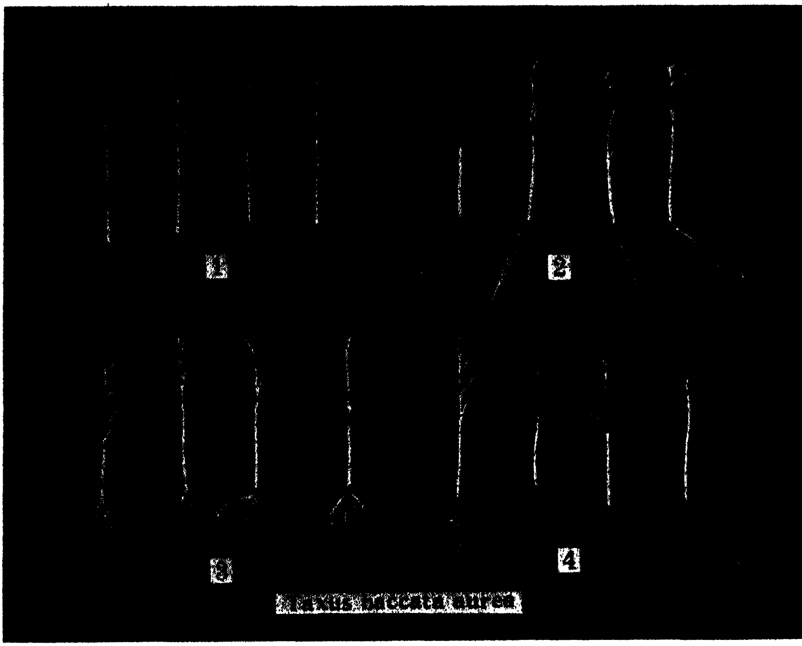

FIG. 3. Rooting of *Taxus baccata aurea* in 94 days. Treatments: (1) water only; (2) 80 parts per million indolebutyric acid (solution); (3) 60 parts per million naphthaleneacetic acid (solution); (4) 30 milligrams indolebutyric acid per gram of talc (powder).

solution treatments resulted in much more uniform root systems within a species than were produced with powder treatments.

DISCUSSION

The desirability of employing hormones in rooting evergreen cuttings in the Puget Sound region was more clearly demonstrated with each succeeding experiment in this series. It seems probable that the propagators in western Washington who have reported poor results with hormones either have not used suitable methods or that the hormones available to them have not been suited to the plant materials on which they were used. The limited number of treatments in which powders were employed in our experiments leaves unanswered questions as to the optimum concentration of powders containing hormones other than indolebutyric acid. However, because of the superior results obtained with indolebutyric acid in solution (except with the yew) it might be expected that this chemical would be equal or superior to others in powder form. Its failure to produce as good results with optimum powder concentration casts considerable doubt upon the practicability of recommending the powder method for this type of plant materials. In any event, indolebutyric powders in concentrations that gave optimum results in our experiments are not now available

commercially. If powders of suitable concentration for dormant evergreen cuttings are made available, they may appeal to amateur propagators because of the ease of application but for large scale commercial use the solution method has no disadvantages that are not outweighed by superior and more rapid rooting response and greater uniformity of the rooted cuttings. Uniform response can be expected only when uniform cuttings absorb equal quantities of the hormone. Several investigators have pointed out that uniform absorption is more likely to occur when the hormone is in solution. Thus Maxon, Pickett and Richey (5) state that the dust method does not permit concise control of quantities of hormones entering the cuttings. They go on to say that the solution method is simple enough for practical use and comparatively exact in its control of concentration and absorption into the cutting. On the other hand, Swartley and Chadwick (6), in discussing experiments with evergreen cuttings say that the talc dusts with their greater ease of application, wider range of effectiveness and less danger of toxicity should be of great benefit to the commercial propagator.

In our experiments no evidence of toxicity of the hormones was encountered. It has often been observed that solution treatments at higher than optimum concentration result in overstimulation, with a large number of relatively short roots. This only emphasizes the need for precise control of hormone concentration and absorption. In our experiments optimum rooting resulted with most species only after treatment with indolebutyric acid solutions of concentrations of 60 to 80 parts per million parts of water. Twenty parts per million more or less than these concentrations gave less desirable results. The failure to obtain as good results with powders as with solutions, even when the concentration of hormone in the powders was increased to 45 milligrams per gram is additional evidence that maximum precision cannot be obtained with powders.

The time of taking cuttings was not studied in our experiments, all cuttings being obtained in late fall months. It is possible that soft or semi-hard cuttings, which are more commonly used in propagating the broadleaved evergreens, would respond better than dormant cuttings to powder treatments. It is interesting, however, that the andromeda, camellia and English holly were rooted readily in late fall after treatment with indolebutyric acid solutions. With these species, dormant cuttings have been difficult or at least slow to root without hormone treatment.

Summary

Experiments with hormone treatment of evergreen cuttings obtained in October and November and rooted with bottom heat at 70 degrees F were carried on over a period of 5 years. Rooting was accelerated and more than 90 per cent of cuttings rooted consistently after 24-hour treatment with indolebutyric acid solutions at concentrations of 60 and 80 parts per million parts of water. A species of yew, *Taxus baccata aurea,* responded better to naphthaleneacetic than to indolebutyric acid, indicating the desirability of further experimentation with this genus.

Powder preparations did not produce as good results as those obtained with solution treatment. The results with powders indicated that hormones available commercially in powder form are not sufficiently concentrated to produce optimum effects with the type of cuttings used in these experiments.

Most of the species rooted equally well in sand and sand-peat. *Camellia japonica* and *Ilex Aquifolium* responded better in sand-peat, whereas *Chamaecyparis plumosa aurea* and *Juniperus hibernica* rooted better in pure sand.

The results obtained in these experiments indicate that propagators of evergreens in the Puget Sound region should use indolebutyric acid solutions at concentrations of 60 or 80 parts per million for treating cuttings taken in late fall and rooted with bottom heat.

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Spray Tests for Azalea Petal Blight

By H. K. Riley and C. J. Daigle, *Southwestern Louisiana Institute, Lafayette, La.*

Azalea petal blight, a fungus disease affecting azalea flowers, has become widespread and very destructive throughout most sections of the South. During the 1947 blooming season in Lafayette, Louisiana, practically all plants of mid-season blooming varieties were seriously infected. The disease is caused by the fungus, *Ovulina Azaleae* (Weiss) which apparently lives only on azalea flowers. The primary infection results from ascospores produced on apothecia arising from sclerotia which have persisted from the previous blooming season in the soil or mulch material under azalea plants. Secondary infection, result from spores produced on the surface of infected petals and spread by wind, insects and contact, is usually very rapid. Infected flowers break down quickly, wilt, and then dry on the plant. On a single plant, the disease will destroy all flowers in from 3 to 5 days under favorable weather conditions, thus shortening the blooming period to that extent from the normal of 10 to 15 days. Plants with damaged flowers present a very unsightly appearance. Preventive spraying of opening flowers with fungicides to reduce or delay infection is, to date, the only practical method of control. The test described herein was designed to evaluate several proprietary compounds which have been suggested as effective for this purpose.

Materials and Methods

Twelve large, uniform plants of *Azalea Indica,* variety Formosa, located on the grounds of the convent of the Most Holy Sacrament in the city of Lafayette, Louisiana were selected for the test. The variety Formosa was used because it blooms in mid-season when blight infection is most severe. The plants were uniform in size and condition of growth and were under identical conditions of exposure, being planted equi-distant along the front line of the property. Surface area of each plant was computed to be approximately 350 square feet. Six units of two plants each were established. One unit located at the center of the row was left unsprayed as a check. The following materials were applied to the remaining five units: Dithane, Phygon, Zerlate, and Koppersol. The sixth unit located at the opposite end of the row from the first unit which was sprayed with Dithane also received applications of this fungicide. Tests conducted in 1946 indicated the special value of this material; therefore, it was chosen as a base material for evaluation of the others.

The fungicides were mixed in accordance with recommendations of the manufacturers. A small power sprayer with pressure regulated at 200 pounds was used. A spray gun with a $^3/_{64}$-inch orifice was adjusted to produce a fine misty spray. Spraying operations were conducted in a manner to assure that each open flower was thoroughly wetted. Each plant received 2½ gallons of spray solution per application. The first application was made on March 29, when about half

the buds on each plant showed color and a few opened flowers were present. Four additional applications were made on March 31, April 2, April 5 and April 7. During this period flowers opened rapidly so that the plants were in full bloom for the fourth and fifth applications. Thus all flowers received a minimum of two spray applications and many received three and four.

During the period of the test, weather conditions were very favorable for development of the disease and unfavorable for spray applications. Humidity was high, there was considerable cloudiness, moderate to heavy winds, and one heavy rain shower soon after the application on April 5. Similar conditions continued during the period of observation following the last spray application which was made on April 15, with heavy wind and rain on April 10, April 11, 12 and 13. During the period of the test, ample opportunity for infection was present. Early blooming varieties across the street from the test plants were heavily infected when the first application was made and infection continued in the area surrounding the test as mid-season plants came into bloom.

Results

On the Dithane sprayed plants all buds opened normally and with the exception of an occasional flower which opened after the last spray application, all flowers remained in an uninfected condition until they aged and shed normally. These plants remained in perfect condition from April 3 when they were considered to be in full bloom until April 13 when wind damage became apparent. It is the opinion of the writers that had the plants been subjected to less severe wind and rain damage, flowers would have persisted for an additional period of several days. This material caused no damage to flower petals and left no unsightly residue.

Phygon gave good control, although a few flowers on each plant became infected during the period of observation following the last spray application on April 7. However, flowers did not persist as long as on the Dithane unit. Following the fourth spray application, serious bleaching of flowers became evident, especially on the side exposed to afternoon sun. This became more apparent as flowers aged until certain parts of the plants presented an unsatisfactory appearance. Bleaching was somewhat less in shaded areas. Spray residues were apparent upon close examination, but this condition was unnoticeable in casual observation at a distance of 10 feet from the plant.

Zerlate gave fairly effective control during the spraying period. However, infection started on these plants on April 8 and observation on April 10, 3 days after the last spray application, showed most flowers to be infected either in early or advanced stages. A white residue was noticeable on the flowers at all times.

Koppersol was not effective, infection setting in during the spray period and running almost parallel with the unsprayed checks. Some petal injury was also noticeable.

Check plants became infected on April 1 and all blossoms were completely destroyed by April 10.

SUMMARY AND CONCLUSIONS

Azalea petal blight can be controlled by frequent applications of an effective fungicidal spray. It is necessary to apply the fungicide to flowers as they open on the plant to prevent infection. Hence, spray applications at 48 hour intervals until the plants are in full bloom are necessary. It is apparent that an individual plant can be protected even thought adjacent plants are left unsprayed and become heavily infected. On the basis of this test, Dithane proved to be an effective material. Phygon gave effective control but caused flower damage in the form of bleaching. This material might be less injurious in shady locations. Other materials tested were not considered satisfactory.

Effect of Particle Size of Vermiculite Media on the Rooting of Cuttings[1]

By F. L. O'Rourke and Marcus A. Maxon, *Michigan State College, East Lansing, Mich.*

Exfoliated vermiculite, a micaceous mineral expanded by heating and commonly advertised for insulating purposes, has been used occasionally during the past few years as a medium for the rooting of cuttings. This material is processed in five particle sizes. The largest has received the trade name of Saniflor and is designated as SF. The diameter ranges from 8 to 12 mm. The No. 1 size ranges from 5 to 8 mm, the No. 2, from 2 to 3 mm, the No. 3, from 1 to 2 mm, and the smallest, No. 4, from .75 to 1 mm. Commercial propagators have disagreed as to the most desirable size to use in the cutting bench. Some have indicated that the larger size grades are superior, but it has not been clear whether this preference is due to the particle size itself or to compaction, inadequate drainage, or improper handling.

Recently, Houston and Chadwick (1) have reported the result of trials between two grades of silica sand and vermiculite size grade No. 2. Cuttings of 18 species were used, of which 14 showed a higher degree of rooting in vermiculite, 2 showed no difference, and 2 showed greater rooting in sand.

The present experiments were started on June 1, 1947, in a pit greenhouse humidified by air-water atomizers as described by O'-Rourke and Moulton (2). Each size grade of vermiculite was placed in equal area plots on the benches, together with a plot filled with a medium grade construction sand commonly used for propagating purposes. For comparison, similar areas were prepared on an open bench in a large, airy greenhouse.

In these experiments the vermiculite was never pressed nor compacted in any way. It was poured loosely from the bag to the bench in a dry state and watered slowly and gently. The cuttings, when inserted, were never firmed with the fingers, but were set gently with water from a water spreader on the end of a hose. The sand was handled in much the same manner but the greater weight of this substance tended to make a more compact medium. Greenhouse temperatures ranged from 75 to 100 degrees F. Bottom heat was never used. Tile benches assured excellent drainage.

Twenty cuttings were used per lot, and uniform lots of each plant species were inserted in the various media at the same time. Watering was done by hand and as often as seemed necessary. All lots of cuttings were removed at the time one lot appeared fairly well rooted and were graded into three classes as regards rooting — heavy, medium, and light.

In order to form a basis for comparison, an index was developed for each lot by simply assigning the arbitrary value of "five" for each cut-

[1]Journal Paper No. 937 of the Michigan Agricultural Experiment Station.
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ting in the heavy class; "three" for each in the medium group; and "one" for each lightly-rooted cutting. The summation of all the cuttings multiplied by their assigned values resulted in an index figure for each particular lot. Table I shows this method of evaluation for cuttings of a typical plant species.

TABLE I—EVALUATION OF ROOTING RESPONSE WITH CUTTINGS OF *Philadelphus Coronarius* IN VARIOUS SIZE GRADES OF VERMICULITE AND IN SAND

Medium	No. Set	Number Rooted			Lot Index*
		Heavy	Medium	Light	
Vermiculite S F	20	5	5	8	48
Vermiculite No 1	20	9	3	7	67
Vermiculite No 2	20	14	3	3	88
Vermiculite No 3	20	8	2	5	51
Vermiculite No 4	20	1	6	7	30
Sand	20	2	7	11	42

*Determined by assigning a value of "5" for each cutting heavily-rooted, "3" for medium rooted, and "1" for lightly-rooted cuttings; multiplying the number in each class by their assigned value, and adding the total.

In the humidified pit greenhouse, 5,640 cuttings representing 282 lots and 32 plant species were used. On the open bench, 2,200 cuttings comprising 110 lots and 18 plant species were employed. Softwood cuttings of ornamental deciduous shrubs, such as Philadelphus, Forsythia, Weigela, Euonymus, Cotoneaster, Spiraea, Chaenomeles, Syringa, Kolkwitzia, Lonicera, and Viburnum, were used for the most part, although some herbaceous species of Euphorbia, Dianthus, Pachysandra, Veronica, Salvia, Nepeta, and Pelargonium were tested as well.

The results of these experiments are totalled in Table II. The No. 2 grade of vermiculite rated highest in summation of index values for the rooting of many diverse kinds of cuttings. One of the factors influencing this superiority may be that the media were handled very gently and no air spaces were lost by compaction. With greater pressure exerted on the media, it could be expected that the superiority would shift in favor of a larger size.

TABLE II—TOTAL OF LOT INDEX NUMBERS FOR 7,860 CUTTINGS REPRESENTING 392 LOTS OF 40 PLANT SPECIES AS PER THE ROOTING RESPONSE IN VARIOUS SIZE GRADES OF VERMICULITE AND IN SAND

Medium	Humidified House	Open Bench	Total
Vermiculite S F	2,101	—	—
Vermiculite No 1	2,282	705	2,987
Vermiculite No 2	2,374	839	3,213
Vermiculite No 3	2,352	851	2,203
Vermiculite No 4	1,887	779	2,666
Sand	1,691	405	2,096

Cuttings of certain plant subjects such as Daphne, Rosa, Spiraea, and Weigela rooted better in the larger-sized particles; others as Buxus, Forsythia, Kolkwitzia, Ligustrum, and Viburnum responded better in the plots filled with the smaller-sized particles. These preferences may be attributed to differences in the oxygen and water require-

ments of the specific plants concerned. The relative degree of rooting as affected by particle size was quite similar under the contrasting conditions existing between the two greenhouses.

Summary

The No. 2 size particle grade of vermiculite with an average diameter of 2 to 3 mm furnishes a satisfactory medium for the rooting of softwood cuttings of many species of deciduous shrubs if care is taken to avoid compaction and both water and drainage are adequately provided.

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Comparison of Quartz Sand, Cinders and Vermiculite in Rooting of Evergreen Cuttings

By A. M. S. Pridham, *Cornell University, Ithaca, N. Y.*

Root production in *Juniperus chinensis Pfitzeriana* and in *Thuja orientalis* was determined for cuttings both treated and not treated with growth regulator and when placed in three types of rooting media under wardian case conditions.

Material and Methods

Cuttings were secured from a half acre block of *Juniperus chinensis pfitzeriana.* The plants were 6 years old and uniform in character. Cuttings of a special strain of *Thuja orientalis* were received from Bagatelle Nurseries, Huntington, Long Island, New York.

Cuttings were made according to standard horticultural procedure. They were selected for age of wood and for size of cutting to insure uniformity. Samples of 25 cuttings constituted an experimental unit. Four units were used in all treatments.

Cuttings were stuck to a uniform depth of 1½ inches as closely as possible. They were "watered in" after sticking and examined after various intervals.

Rooting Media

Cinders were obtained from the Cornell heating plant. They were screened through ¼-inch screen to eliminate large particles. They were screened through ⅛-inch screen to eliminate the dust like particles. The remainder was used as a rooting media. Cinders disintegrate during use so that the proportions of small sized particles increase with time.

Vermiculite of 1945–46 vintage and of coarse grade was used without screening.

Sterile quartz sand of 3/16-inch diameter was used after previous tests had indicated that smaller particle sizes did not yield good results with cuttings of woody ornamentals. Larger particle sizes were omitted for the same reason.

Growth regulators were applied by placing an inch and a half of solution in a clean 1 pound butter jar. After tying the cuttings in bundles with the butts level they were allowed to soak for periods of 12 hours prior to sticking.

Results

The results are summarized in Tables I and II.

With both plants: (a) the greatest rooting occurred in the cuttings treated with the growth regulator; (b) earlier rooting was also consistent and indicated that in 50 days a larger return was realized than from the untreated cuttings at the end of 140 days; (c) maximum rooting occurred within 100 days regardless of the rooting media; (d) the influence of the rooting media is minor. Cinders proved consistently the best with vermiculite second and quartz sand third.

TABLE I—*Thuja orientalis* (BAGATELLE SELECTION) PER CENT CUTTINGS ROOTED AFTER STICKING FEBRUARY 14, 1947 (WARDIAN CASE 75 DEGREES F APP. 3 MEDIA)

Rooting Media	Growth Regulator	Days From Sticking to Examining						Average
		50	60	75	100	120	140	
Cinders	Control	0	0	0	20	0	32	8.6
	I.B. 100 ppm	42	36	58	40	44	34	42.3
Vermiculite	Control	0	0	4	10	18	6	6.3
	I.B. 100 ppm	0	14	22	12	22	19	15.0
Sand	Control	0	0	0	7	2	7	2.6
	I.B. 100 ppm	6	6	14	17	18	8	11.5
Average	Control	0	0	1.3	12.3	12.0	13.0	5.6
	I.B. 100 ppm	16	18.6	31.3	23.0	23.0	20.0	22.9

All mean values carry odds of 100:1 and more.

TABLE II—*Juniperus chinensis Pfitzeriana*, PER CENT CUTTINGS ROOTED AFTER STICKING FEBRUARY 14, 1947 (WARDIAN CASE 75 DEGREES F, APP. 3 MEDIA)

Rooting Media	Growth Regulator	Days From Sticking to Examining						Average
		50	60	75	100	120	140	
Cinders	Control	2	4	2	3	12	9	5.3
	I.B. 100 ppm	22	42	50	66	40	53	45.5
Vermiculite	Control	0	2	0	1	6	6	2.5
	I.B. 100 ppm	18	26	24	44	42	59	35.5
Sand	Control	0	0	0	0	0	1	0.1
	I.B. 100 ppm	0	6	12	4	26	14	10.3
Average	Control	0.6	2.0	0.6	1.3	6	5.3	2.9
	I.B. 100 ppm	13.3	24.0	28.0	38.0	36.0	42.0	30.3

All means carry odds of 100:1 and more.

SUMMARY

1. Differences in rooting due to the media are small.
2. Differences due to growth regulator are:
   (a) Greatest of those studied.
   (b) Produce early rooting.

A Preliminary Report on the Pre-Storage Defoliation of Some Trees and Shrubs

By L. C. Chadwick and Rayford Houston, *Ohio State University, Columbus, Ohio*

It is characteristic of many young woody ornamental plants and fruit trees in the nursery to hold their leaves well beyond the end of the growing season. To nurserymen who must dig this stock for shipping or storage this lack of ready defoliation as cold weather approaches presents an important problem. Plants with leaves, tiered in nursery storages, must be reworked during the winter months to eliminate the leaves and to avoid loss from fungus development. The purpose of these tests was to find a suitable spray or dust that was cheap, that could be easily applied previous to digging and that would cause satisfactory defoliation in a relatively short time without injury to the plants.

Several methods of defoliation are now practiced by nurserymen but most of these must be carried out in storage rather than in the field. Removal of leaves by hand or mechanical stripping and by sweating is either a slow and expensive operation or injurious to the plants. Undercutting the plants a few weeks before time of digging is partially effective as a means of defoliation.

Various spray materials have been advocated at one time or another for defoliation of plants, such as sulfuric acid, copper sulfate and sodium arsenite. Few of these have been used with any great success, especially with ornamental plants. Milbrath, Hanson and Hartman (4) advocate the use of ethylene gas as a means of defoliating roses in Oregon. This method requires the construction and use of special chambers, and closely controlled temperatures and humidities, consequently, this method is limited in its adaptation.

Recently, reports (1, 3) indicate that Aero Defoliant, a Cyanamid product, has given satisfactory results with some field crops and fruit plants. Aero Defoliant, applied in dust form has resulted in satisfactory defoliation of cotton and tomatoes when applied at the rate of 30 to 35 pounds per acre, of soybeans at the rate of 100 pounds per acre, young peach trees in the nursery at the rate of 75 pounds per acre and young apple trees at the rate of 100 pounds per acre.

Several other materials such as dinitro orthro secondary butyl phenol (2), other dinitro compounds and ammonium nitrate have been advocated for destroying the tops of various agronomic crops or have caused partially leaf burning and defoliation when applied to fruit trees for other purposes. The possibility of the use of some of these materials for the pre-storage defoliation of nursery stock, along with other compounds, was investigated in these experiments.

Preliminary tests were conducted during the fall of 1945 and although tests were continued during the fall seasons of 1946 and 1947, many problems yet remain to be studied and the presentation of our findings at this time, must be considered in the light of a progress report.

Materials and Methods

The tests conducted during the fall of 1945 consisted of spraying several kinds of ornamental plants (Table I) with various materials. The spray materials used and the concentrations are given below:

1. Elgetol (Sodium 3,5–dinitro–ortho–cresylate) — concentrations of 2 pints per 100 gallons of water and 4 pints per 100 gallons.
2. Ammonium nitrate (NH_4 NO_3) — concentrations of 10 pounds per 100 gallons of water and 20 pounds per 100 gallons of water.
3. Cyanamid (NH_2 CN) — concentrations of 15 pounds per 100 gallons of water and 30 pounds per 100 gallons of water.
4. Nacconol NR (sodium salts of alhylated benzene sulfonic acid)
   (a) 1 per cent and 2 per cent solutions.
   (b) These solutions plus 3 per cent and 6 per cent summer oil emulsion.
   (c) These solutions plus 3 per cent and 6 per cent Velsicol (ethyl naphthalene-toxic oil emulsion).
5. Nacconol HG
   (a) 1 per cent and 2 per cent solutions.
   (b) These solutions plus 3 per cent and 6 per cent summer oil emulsion.
   (c) These solutions plus 3 per cent and 6 per cent Velsicol.
6. Alpha Naphthaleneacetic acid — 1000 ppm and 2000 ppm plus carbowax.
7. Dinitro–O–Secondary butyl phenol (C_{10} H_{12} N_2 O_5) — 1 pound per 100 gallons of water.
8. Sodium arsenite (Na_3 As O_3) — 25 pounds and 12.5 pounds per 100 gallons of water.

Most of the plants sprayed in 1945 and 1946 were several years old and with the exception of the roses, and some of the Viburnums listed in Table II. They were grown as hedges in the department's hedge collection. Sprays were applied with a hand sprayer, and observations were made on the effectiveness of the defoliation several times during the fall. Results were recorded on the degree of defoliation in approximately 7 to 14 days.

Since the best results (Table I) in 1945 were obtained with Nacconol NR, further tests were carried out with this material in 1946, to obtain additional information on the best concentration to use. The results of the 1946 tests are recorded in Table II.

The tests conducted during the fall of 1947 consisted of spraying several hundred nursery size apple and peach trees, some raspberries and a few roses. Nacconol NR was used throughout in these tests, with oil, as indicated in Table III. The spray material was applied with a small 12 gallon power sprayer that developed 100 to 125 pound pressure.

Discussion

The data given in Table I indicate that the degree of defoliation will vary with the plant species sprayed and with the kind and concentra-

TABLE I—DEFOLIATION OF SOME SHRUBS AND TREES (1945)

Material and Concentration	Date of Application	Extent of Defoliation on October 18, 1945							
		Berberis mentorensis	*Cotoneaster divaricata*	*Euonymus europaeus*	*Ligustrum ibolium*	*Lonicera maacki*	*Quercus imbricaria*	*Rhamnus davurica*	*Viburnum lantana*
Nacconol NR (1 per cent plus 3 per cent summer oil)	Oct 10	Slight	Nearly complete	Nearly complete	Half	Half	Nearly complete	—	Three-fourths
Nacconol NR (1 per cent plus 3 per cent Velsicol)	Oct 11	Slight	Nearly complete	Nearly complete	Half	Half	Half	—	Three-fourths
Nacconol NR (2 per cent)	Oct 27	—	—	—	Three-fourths**	—	—	Slight*	—
Nacconol HG (1 per cent plus 3 per cent summer oil)	Oct 11	Slight	Nearly complete	Nearly complete	Half	Half	Half	—	Three-fourths
Nacconol HG (1 per cent plus 3 per cent Velsicol)	Oct 11	Slight	Nearly complete	Nearly complete	Half	Half	Half		Three-fourths
Nacconol HG (2 per cent)	Oct 30	—	—	—	Three-fourths**	—	—	Slight*	—
Nacconol NR (2 per cent plus 6 per cent summer oil)	Oct 27	—	—	—	Nearly complete**	—	—	Nearly complete	—
Nacconol NR (2 per cent plus 6 per cent Velsicol)	Oct 30	—	—	—	Three-fourths**	—	—	Three-fourths*	—
Nacconol HG (2 per cent plus 6 per cent summer oil)	Oct 30	—	—	—	Three-fourths**	—	—	Three-fourths*	—
Nacconol HG (2 per cent plus 6 per cent Velsicol)	Oct 30	—	—	—	Three-fourths**	—	—	Nearly complete*	—
Elgetol (2pt/100 gal)	Oct 4	—	Very slight	Slight	Slight	Slight	Very slight	—	Slight
Elgetol (4 pt/100 gal)	Oct 20	—	—	—	Slight**	—	—	Very slight	—
Ammonium nitrate (10 lb/100 gal)	Oct 4	—	Slight	Slight	Slight	Slight	Slight	—	Slight
Ammonium nitrate (20 lb/100 gal)	Oct 20	—	—	—	Slight**	—	—	Three-fourths*	—
Cyanamid (15 lb/100 gal)	Oct 9	—	Slight	Slight	Very slight	Slight	Slight	—	Half
Cyanamid (30 lb/100 gal)	Oct 30	—	—	—	Three-fourths**	—	—	Half*	—
Alpha naphthalene acetic acid (2,000 ppm plus carbowax)	Oct 20	—	—	—	—	—	—	Very slight*	—
Dinitro-O-Secondary butyl phenol (1 lb/100 gal)	Nov 5	—	—	—	Slight**	—	—	—	—
Sodium Arsenite (12½ lb and 25 lb, 100 gal)	Oct 11 Oct 30	With both concentrations, the leaves turned brown within 2 to 4 days on most of the plants sprayed, but they failed to drop and there was some injury to the young shoots.							

*Date recorded Nov 9, 1945.
**Data recorded Dec 6, 1945.

TABLE II—DEFOLIATION OF SOME SHRUBS AND TREES
(DATA RECORDED NOVEMBER 14, 1946)

Plants Sprayed	Material and Concentration		
	Nacconol NR (1 Per Cent Plus 3 Per Cent Summer Oil) (Applied Oct 26, 1946)	Nacconol NR (2 Per Cent) (Applied Oct 28, 1946)	Nacconol NR (2 Per Cent Plus 3 Per Cent Summer Oil) (Applied Nov 2, 1946)
	Extent of Defoliation		
Acanthopanax sieboldianus	Half	Slight	Half
Acer tataricum	Nearly complete	Nearly complete	Nearly complete
Berberis mentorensis	Slight	Slight	Slight
Berberis, Columnberry	Slight	Three-fourths	Nearly complete
Cotoneaster divaricata	Nearly complete	Nearly complete	Nearly complete
Fagus sylvatica	Slight	Half	Half
Ligustrum ibolium	Half	Slight	Half
Lonicera maacki	Half	Three-fourths	Three-fourths
Quercus imbricaria	Slight	Slight	Slight
Quercus robur	Half	Three-fourths	Half
Rhamnus frangula	Slight	Three-fourths	Three-fourths
Roses, H. T.	———	Slight to half	Slight to half
Viburnum burkwoodi	———	———	Three-fourths
Viburnum lantana	Nearly complete	Nearly complete	Nearly complete
Viburnum macrocephalum sterile	———	———	Nearly complete
Viburnum opulus	———	Slight	Nearly complete
Viburnum opulus nana	———	———	Three-fourths
Viburnum rhytidophyllum	———	———	Half

tion of the spray material used. Elgetol, ammonium nitrate, alpha naphthalene acetic acid, dinitro–o–secondary butyl phenol and sodium arsenite, in the manner and concentrations used, were not effective in causing adequate defoliation of the plants sprayed. Cyanamid showed promise but its use has not been continued in these tests.

Nacconol NR and Nacconol HG showed considerable promise in the preliminary tests of causing effective defoliation of several ornamental shrubs. Nacconol NR was as effective as Nacconol HG and it is somewhat more economical to use. The addition of oil to the Nacconols seem to increase their effectiveness to some extent. A safe, summer oil was as effective as Velsicol. One per cent Nacconol NR plus 3 per cent summer oil constitutes an effective defoliant of *Cotoneaster divaricata, Euonymus europaeus* and *Viburnum lantana*. A stronger concentration will be required to defoliate many ornamental shrubs effectively.

The results of the spray applications made in the fall of 1946, were checked at frequent intervals with the final data (Table II) compiled November 14, 1946. Some effect of the Nacconol sprays was apparent within 2 to 4 days. This early effect consisted primarily of browning of the foliage, but in addition, some foliage drop with such plants as *Cotoneaster divaricata* and *Viburnum lantana*. In most cases defoliation occurred within 7 to 10 days. As the earlier results indicated, whereas the lower concentration, 1 per cent Nacconol plus 3 per cent oil, is effective in causing defoliation of a few shrubs, a stronger concentration of 2 per cent Nacconol plus 3 per cent oil, will be a more desirable concentration to use for most shrubs. The earlier the defoliation is attempted, the stronger will need to be the concentration. No apparent injury has resulted from the applications of Nacconol to any of the ornamental plants.

The data presented in Table III indicate that a 2 to 2½ per cent Nacconol NR solution, with a 3 per cent summer oil, can be used safely and effectively for the defoliation of 1- to 2-year-old apples and apple seedlings in the nursery. Applications will accomplish defoliation in 7 to 10 days, depending upon the time of year the spray is applied and the weather conditions.

There was no apparent injury to the buds or twigs of the apples even where a 4 per cent Nacconol solution was applied. Whether any injury develops in storage remains to be checked, but such injury is not anticipated. It is very difficult to cause the defoliation of the tip leaves of the shoots. If the defoliant is applied too early some new tip growth may develop. The applications of Nacconol and oil were effective in cleaning up a rather heavy infestation of woolly aphis on the apple seedlings.

Spraying peaches with 1½ and 2 per cent Nacconol, with a 3 per cent oil, in early October did not cause satisfactory defoliation. Stronger concentrations applied approximately 3 weeks later caused complete defoliation in 3 to 4 days; however, these stronger solutions caused stem injury. On November 11th, two plants from each of the treated peach plots were dug and placed in a 45 degrees F mechanically cooled storage. After being in storage for 30 days, they were removed, planted in tubs and placed in a 65 degrees F greenhouse. On December 19th, the following notes were taken on these plants:

1½ per cent Nacconol NR plus 3 per cent oil — A few brown spots on main stems; tips of shoots killed back about 2 to 3 inches; no injury to the buds. This dying back of shoot tips may also occur on non-sprayed plants.

2 per cent Nacconol NR plus 3 per cent oil — In practically the same condition as those sprayed with the 1½ per cent concentration; possibly less injury.

2½ per cent Nacconol NR plus 3 per cent oil — Considerable spot browning of the main stems; small, weak twigs completely killed; ends of main branches killed back 4 to 6 inches; no injury to buds on live wood.

3 per cent Nacconol NR plus 1½ per cent oil — Burn on main stems not as extensive as where 2½ per cent solution applied. Small, weak twigs completely killed; ends of main branches killed back 4 to 6 inches; no injury to buds on live wood.

3½ per cent Nacconol NR plus 3 per cent oil — Severe burn on main stem. Smaller twigs completely killed and tips of main branches killed back 8 to 10 inches; no injury to buds on live wood.

4 per cent Nacconol NR plus 3 per cent oil — Injury slightly more extensive than where 3½ per cent solution applied.

From these notes it appears that concentrations of over 2 per cent Nacconol NR may cause excessive injury to peach. Observation of the sprayed trees showed that most of the burning on the main stem was on the north and east exposures. This suggested that temperature may have been an influencing factor and that the oil and not the Nacconol

TABLE III—DEFOLIATION OF SOME FRUITS AND ROSES WITH CERTAIN CONCENTRATIONS OF NACCONOL NR AND 3 PER CENT SUMMER OIL (1947)

Plant and Location	No. of Plants Sprayed	Date of Application	Concentration of Nacconol	Date of Observation and Remarks
Red Delicious Apples 1 and 2 year plants Scarff Nursery	Total 305 Plot 1—216 Plot 2—89	Oct 4, 1947	Plot 1— 1½ per cent Plot 2— 2 per cent	Oct 7, 1947—One-third to one-half of leaves show browning; very few leaves fall when plants shaken Oct 12, 1947—1½ per cent concentration—one-eight or less of leaves fallen 2 per cent concentration—one-half to three-fourths of leaves browned; one-fourth of leaves fallen; petioles looser on remaining than on checks or those sprayed with 1½ per cent Nacconol Oct 19, 1947—1½ per cent concentration—one-fourth to one-half leaves fallen; 2 per cent concentration—three-fourths to complete defoliation; some new growth at tips of shoots; check plants holding 100 per cent of leaves Oct 30, 1947—1½ per cent concentration—better than 50 per cent defoliation 2 per cent concentration—75 to 100 per cent defoliation; no indication of bud or twig damage
Malus baccata mandschurica Seedlings Ohio State University Nursery	50	Oct 14, 1947	2 per cent	Oct 15, 1947—Considerable burning of foliage but no leaf fall Oct 16, 1947—Petiole loosening but no leaf fall Oct 18, 1947—One-fourth leaves fallen Oct 20, 1947—50 per cent of leaves fallen Oct 23, 1947—75 to 100 per cent leaves fallen Oct 26, 1947—Approximately complete defoliation; no apparent damage to twigs or buds
Apple Seedlings 2 year plants Ohio State University Nursery	Total—250 50 in each plot	Oct 14, 1947	Plot 1— 2 per cent Plot 2— 2½ per cent	Oct 14, 1947—Burning of leaves noticed in 2 hours after spraying Oct 15, 1947—One-half to three-fourths of leaves severely burned Oct 16, 1947—No defoliation Oct 20, 1947—One-eighth to one-fourth of leaves fallen; by shaking the plant. 50 per cent of leaves fall Oct 23, 1947—One-half to three-fourths of leaves fallen; rest loose Oct 26, 1947—2 per cent concentration—80 to 100 per cent of leaves fallen 2½ per cent concentration—90 to 100 per cent of leaves fallen Just a few leaves near the tip of shoot Some new tip growth in warm October
		Oct 22, 1947	Plot 1— 3 per cent Plot 2— 3½ per cent Plot 3— 4 per cent	Oct 22, 1947—All showed severe burning of foliage in 3 hours after spraying Oct 23, 1947—Complete browning of leaves but no defoliation Oct 26, 1947—3 per cent concentration—no leaf fall 3½ per cent concentration—one-eighth of leaves fallen 4 per cent concentration—one-eighth of leaves fallen Oct 20, 1947—50 to 75 per cent defoliation on all; other leaves loose Nov 13, 1947—Complete defoliation; some new tip growth being produced; no indication of bud to twig injury

TABLE III — *continued*

Belle of Georgia Peaches 2 year plants Scarff Nursery	Total 114 Plot 1—48 Plot 2—66	Oct 4, 1947	Plot 1— 1½ per cent Plot 2— 2 per cent	Oct 7, 1947—Browning of leaves near base of plants; one-third leaves fall if plants shaken Oct 12, 1947—One-third of leaves fallen from base of plants; upper two-thirds of plant retaining leaves; falling occurred within 4 days Oct 19, 1947—No additional leaf drop; petiole still tight on leaves remaining; buds show no sign of damage Checking every week through the rest of October and half of November, no additional leaf fall in excess of normal; normal date of leaf fall, about November 15
Champion, Big Red and Hale Haven Peaches 2 year plants Scarff Nursery	Total 102 Plot 1—20 Plot 2—23 Plot 3—25 Plot 4—34	Oct 23, 1947	Plot 1— 2½ per cent Plot 2— 3 per cent Plot 3— 3½ per cent Plot 4— 4 per cent	Oct 30, 1947—100 per cent defoliation from all concentrations; leaves fell in 3 to 4 days after spraying; no apparent bud or twig damage Nov 6, 1947—Some injury apparent, mostly with 3½ per cent and 4 per cent concentrations; injury mostly to tips of shoots and to weak side wood See discussion for further notes; 1½ per cent oil used with 3 per cent concentration
St. Regis Raspberries Scarff Nursery	Approximately 1000, 335 in each plot	Oct 30, 1947	Plot 1— 3 per cent Plot 2— 3½ per cent Plot 3— 4 per cent	Nov 6, 1947—All foliage browned; one-fourth to one-half defoliation; no sign of bud or twig injury Nov 13, 1947—One-half to three-fourths defoliated; leaves remaining on tips Dec 4, 1937—All foliage off from check and treated plants; no apparent injury to sprayed plants
Roses, Hybrid Teas Ohio State University Gardens	Total 15 Plot 1—12 Plot 2—3	Oct 14, 1947	Plot I— 2 per cent Plot 2— 2½ per cent	Oct 15, 1947—2 per cent concentration—no effect 2½ per cent concentration—small amount of leaf burning Oct 16, 1947—2 per cent concentration—slight burning of foliage 2½ per cent concentration—petioles loosening but no leaf fall Oct 20, 1947—Both concentrations—one-half to three-fourths of leaves fall when plant shaken Oct 24, 1947—2 per cent concentration—75 to 95 per cent defoliation, depending on variety; leaves left are at the shoot tips 2½ per cent concentration—approximately 95 per cent defoliation; leaves left are at the shoot tips; some new growth produced after spray applied Oct 26, 1947—Tip leaves still remain Tip leaves held until time of normal fall; no apparent damage to buds or twigs on sprayed plants
	Total 10 Plot 1—5 Plot 2—5	Oct 22, 1947	Plot 1— 3½ per cent Plot 2— 4 per cent	Oct 24, 1947—3½ per cent concentration—slight leaf burn, no drop 4 per cent concentration—one-half to three-fourths leaves burned, no drop Oct 26, 1947—3½ per cent concentration—one-fourth to one-half leaves burned; 50 per cent defoliation if plants shaken 4 per cent concentration—one-half to three-fourth leaves burned; 50 per cent defoliation if plants shaken Oct 30, 1947—3½ per cent concentration—90 per cent defoliation; few leaves remain at tip of shoots 4 per cent concentration—95 per cent defoliation; few leaves remain at very tip of shoots Nov 13, 1947—Few leaves remaining at very tip of shoots; plants made some new growth following spraying, indicating no apparent injury to buds or stems

caused the injury. The use of a 1½ per cent oil with the 3 per cent Nacconol also indicated that the higher concentrations of oil may have been responsible for the injury.

Following the applications on October 23rd the temperature dropped from 83 degrees F to 49 degrees F in 16 hours. The lowest temperature over a 24-hour period following the applications on October 4th was 57 degrees F.

It is characteristic of peaches sprayed with Nacconol and oil to show the full extent of the resulting defoliation in 3 to 4 days after the spray is applied.

Three per cent solutions of Nacconol NR plus 3 per cent oil caused up to 75 per cent defoliation of St. Regis raspberries in 7 to 10 days. Even 4 per cent solutions caused no apparent injury to stems or buds. The temperature did not fall below 50 degrees F for 24 hours after the applications were made, in fact, the temperature did not vary more than 7 degrees during this period.

Two to 2½ per cent solutions of Nacconol NR with 3 per cent summer oil were effective in causing up to 95 per cent defoliation of hybrid tea roses in 8 to 10 days. Most of the leaves remaining on the plants were at the very tip of the shoots and these remained until the time of normal leaf fall. Since the rose canes would be cut back to some extent in shipping or storage, the few remaining leaves at the tip of the shoots would not be a serious fault of this treatment. Solutions of Nacconol NR up to 4 per cent, with 3 per cent oil, caused no apparent injury to stems or buds.

Some recent information suggests that wettable sulfur might replace the oil in the solutions with equal effectiveness and that two applications of a weaker concentration of Nacconol several days apart may be more effective in causing adequate defoliation than one application of a stronger solution.

Summary

Pre-storage defoliation of nursery stock is an important problem to many nurserymen. No method is now practiced commercially, whereby adequate early defoliation is accomplished previous to digging.

The experiments reported here indicate that sprays of Nacconol NR plus a summer oil will cause satisfactory defoliation of several kinds of nursery stock. The degree of defoliation will vary with the plant species, the kind and concentration of the material applied and the time of year the application is made. The earlier the application is made in the fall, the stronger must be the concentration to cause satisfactory defoliation.

One per cent solution of Nacconol NR, with a 3 per cent summer oil, was effective in causing premature defoliation of *Acer tataricum*, *Cotoneaster divaricata*, *Euonymous europaeus* and *Viburnum lantana*. A 2 per cent solution of Nacconol NR, with a 3 per cent summer oil, was effective in causing from 75 per cent to complete defoliation of Columnberry Barberry, *Ligustrum ibolium*, *Lonicera maacki*, *Quercus imbricaria* and *Q. robur*, *Rhamus davurica* and *R. frangula*, and *Viburnum burkwoodi*, *V. macrocephalum sterile*, *V. opulus*, and *V.*

opulus nana. In most cases, defoliation will occur within 7 to 10 days after the application is made. No injury to stems or buds have been apparent following the use of these concentrations.

Two to 2½ per cent Nacconol NR solutions, with a 3 per cent summer oil, are effective in causing 75 to 100 per cent defoliation of 1- to 2-year-old apples, apple seedlings and roses in 7 to 10 days following application. Remaining foliage is confined mainly to the very tips of the shoots. No twig or bud injury has been apparent following these spray applications. A 3 per cent solution of Nacconol NR, the lowest concentration used, with 3 per cent summer oil, was effective in causing 75 per cent or more defoliation of St. Regis raspberries in 7 to 10 days without apparent injury to stems or buds.

The 1½ and 2 per cent solutions of Nacconol NR, with 3 per cent summer oil, were not effective in causing satisfactory defoliation of young peach trees, when they were applied in early October. The 2½, 3, 3½ and 4 per cent solutions of Nacconol NR with 3 per cent summer oil, applied 3 weeks later, caused 100 per cent defoliation in 3 to 4 days but also resulted in considerable injury to twigs and main branches of the plants. It is possible, under the temperature conditions existing when the applications were made, that the oil, at least when combined with the lower concentrations of Nacconol, was responsible for the injury, and not the Nacconol.

Further researches may show that wettable sulfur can be substituted for the oil and that two applications of a weaker concentration of Nacconol will be more effective in causing premature defoliation than one application of a stronger concentration.

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Effect of Concentration of 2,4–D, Rate of Application, and Respraying, on Killing Japanese Honeysuckle[1]

By A. E. Hitchcock and P. W. Zimmerman, *Boyce Thompson Institute for Plant Research, Inc., Yonkers, N. Y.*

A 0.2 per cent solution of 2,4–Dow weed killer applied at 1.5 to 4.2 gallons per square rod caused 90 to 100 per cent killing on sparse stands of honeysuckle in shaded areas and 50 to 99 per cent killing on dense stands 8 to 10 years old growing in the open. Only 2 of 20 plots receiving 0.2 per cent 2,4–D showed 100 per cent kill. Equivalent quantities of 2,4–D did not cause the same degree of killing, the location of the plants with respect to shade and the time of year sprayed being more important than concentration or rate of application in the range 0.1 to 0.2 per cent and 1.5 to 4.2 gallons per square rod. Results with a 2-gallon Hudson Junior sprayer on 100 square foot plots were essentially the same as those obtained with a 50-gallon estate power

TABLE I—Effect of Concentration of 2,4–D, Rate of Application, and Respraying on Killing Japanese Honeysuckle

Size of Plot (Sq Ft)	Treatment: Concentration (Per Cent)	Treatment: Rate (Gal/Sq Rd)	No. Shoots* Per Sq Ft (Oct 8, 1946)	Length of Regrowth (Inches)*	Per Cent** Regrowth
		Sprayed May 20, 1946			
544	0.1	2.3	20	7	65
	0.1	4.2	10	8	33
	0.2	1.75	17	8	57
	0.2	2.75	3	5	8
100	0.1†	2.3	13	9	42
	0.1	4.2	22	16	72
	0.2	1.75	18	9	58
	0.2	2.75	10	7	33
100	0.1	1.5	22	17	72

One-half of above (544 sq. ft.) plots resprayed July 3, 1946

Size of Plot (Sq Ft)	Concentration: May 20	Concentration: July 3	Rate: May 20	Rate: July 3	No. Shoots* Per Sq Ft (Oct 8, 1946)	Length of Regrowth (Inches)*	Per Cent** Regrowth
272	0.1	0.1	2.3	1.5	0.14	3	<0.01
	0.1	0.2	4.2	1.5	5	4	17
	0.2	0.1	1.75	2.5	0.07	2	<0.01
	0.2	0.2	2.75	2.5	3	3	10

Size of Plot (Sq Ft)	Treatment: Concentration (Per Cent)	Treatment: Rate (Gal/Sq Rd)	No. Shoots* Per Sq Ft (Oct 8, 1946)	Length of Regrowth (Inches)*	Per Cent** Regrowth
		Sprayed July 3, 1946			
544	0.1	1.5	8	4	27
	0.1	3.0	9	4	30
	0.2	1.5	15	5	50
	0.2	3.0	7	3	24
100	0.1	1.5	8	4	27
	0.1	3.0	5	9	16
	0.2	1.5	11	7	37
	0.2	3.0	5	3	17

*Average of four counts.
**Based on non-treated control plot which averaged 30 shoots per square foot, 36 inches in length.
†Plot shaded most of day.

[1][Ed.] Received by the Society October 12, 1946 for Volume 49 of the Proceedings which was published June 1947, but in which through accident this article was not included.

sprayer on plots 544 square feet in area. Sprays applied July 3, 1946, were more effective than those applied May 20 or August 8, the latter being least effective (<50 per cent initial kill). Although a 0.2 per cent spray applied July 3 caused a high initial kill (95 to 100 per cent) of the current season's growth, considerable regrowth from older stems occurred after 6 weeks. A second spray (0.1 per cent or 0.2 per cent at rate of 1.5 to 3.0 gallons per square rod) applied July 3 to one-half of the plots sprayed on May 20 (also to plots sprayed in August, 1945) caused rapid killing of all regrowth shoots and a greater degree of disintegration of stems and roots than resulted from the single spray of July 3. A few shoots (<0.01 per cent) grew eventually in the resprayed areas.

Results for the May and July sprays applied to well established stands 100 square feet and 544 square feet (2 square rods) in area are shown in Table I. A total of 600 gallons of 0.1 to 0.2 per cent 2,4-D were applied to other areas ranging in size from 250 to 9,000 square feet and varying both in density of stand and exposure to direct sunlight. On the basis of these results more than one application of 2,4-D is recommended during the period May to July inclusive, for killing well established stands of Japanese honeysuckle in the region of New York City. Sparse stands particularly in shaded areas showed less than 1 per cent regrowth after applying one spray (May 20 to July 3). Virginia creeper, wild strawberry, wild lettuce, wild snapdragon, joe-pye weed, poison ivy, wild blackberry, Solomon's seal, oxalis, and cinquefoil were not entirely eradicated in honeysuckle plots sprayed with 0.1 per cent or 0.2 per cent 2,4-D.

Fruit Breeding — Past, Present and Future[1]

By W. H. ALDERMAN, *University of Minnesota, St. Paul, Minn.*

FRUITS have always been a favorite food of man and fruit culture is one of the earliest forms of agriculture. There is general agreement that fruits such as the date, fig and grape were highly regarded by the ancients and were grown under some form of cultivation as early as 3000 or 4000 years before Christ. Did this so called "cultivation" involve anything beyond the more or less casual protection of trees or plants which had grown naturally without plan or preparation? Or had agriculture, in some areas at least, developed to the point where superior size, color, quality or productivity of fruits were appreciated and efforts were made to grow the better types? These questions cannot be answered with authority and the first modest beginning of fruit improvement or fruit breeding cannot be precisely dated.

It seems clear that even unconscious efforts at fruit improvement through the selection and maintenance of desirable individual seedlings must have been preceded by some knowledge of the art of vegetative propagation. Some primitive gardener at a very early period may have learned about layerage by observing a new plant rooting and growing from a trailing grape vine. Similarly propagation by cuttings may have been discovered when some one observed that shoots or branches of the easily rooted fig grew into trees after being thrust into moist ground, perhaps by children at play. The discovery of these simple methods of vegetative propagation, however and whenever it occurred, became the first significant milestone in the development of the art and science of modern fruit growing, including fruit breeding or improvement. As time went on the more complex arts of grafting and budding were discovered at least several centuries prior to the Christian era.

After the gardener learned that he could maintain and increase in numbers his favorite vine or fig tree, it became possible for him to begin a conscious selection of superior individuals and to establish horticultural varieties. In the broadest sense of the term this would constitute a form of fruit breeding. Indeed it marked the beginning of a method of breeding and improvement still in common use, namely the selection of chance seedlings. This method, incidentally, has given to the world tens of thousands of horticultural varieties and accounts for the origin of such widely grown fruits as Baldwin, Delicious, Golden Delicious, McIntosh and Winesap apples; Bartlett, Kieffer and Seckel pears and the J. H. Hale peach. These and many others too numerous to mention were originally chance seedlings.

Between this simple recognition and propagation of "Gift of God" varieties and modern plant breeding methods lies a diversity of procedures and practices of varying degrees of complexity. All, however, point to a common goal — the production of a variable or segregating population from which individuals of a desirable type may be selected.

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The first simple refinement of breeding methods involved the deliberate planting of fruit seeds for the purpose of growing a seedling population as material for selection. Because of the heterozygous nature of essentially all kinds of fruits the individuals of such a population will vary one from another and may produce one or more seedlings with superior or desirable qualities that may be selected, propagated and introduced as new varieties. If the seeds originally planted were taken from varieties that possessed certain desirable qualities which it was hoped might be transmitted to some of the offspring a further refinement of breeding methods was added. The fruit breeder in these cases merely needed to have a comprehensive knowledge of existing varieties of the kind of fruit or fruits with which he was working to enable him to make critical selections. Thus, did Ephriam Bull select the Concord grape, Samuel Rumph the Elberta peach and Peter Gideon the Wealthy apple. The outstanding example of the possibilities inherent in the simple breeding by selection method is found in the classical experiment in pear breeding by Van Mons in Belgium begun in the closing years of the 18th century. His theory that seed from the first borne fruit of young trees produces higher quality in resulting seedlings than does seed procured from old trees is now discredited but he did demonstrate that much could be accomplished by selections from large populations of seedlings. At one time he is reported to have had 80,000 seedlings in his nursery. Van Mons introduced more than 400 varieties and numbered selections of pears including such important varieties as Bosc and Manning's Elizabeth. Considering all varieties of all kinds of fruits that have been produced throughout the world it is safe to say that 95 per cent or more have been derived by some type of simple selection.

While Van Mons in Belgium was demonstrating the potentialities in breeding by selection an English horticulturist, Thomas Andrew Knight, was applying for the first time the recently discovered science of plant hybridization to a practical and systematic breeding program with fruits. The success of his experiments in producing superior seedlings by crosses between varieties was notable from the standpoint of scientific as well as practical fruit breeding. Several of his introductions are still grown in Europe and the United States. If the discovery of vegetative propagation was the first milestone on the highway of fruit culture and improvement, the second milestone was the one erected by Thomas Andrew Knight when he so ably demonstrated the value and usefulness of hybridization as a method of fruit breeding. After 150 years we are still travelling within the third mile.

The principal purpose of this paper is to review as specifically as possible the activities and accomplishments in fruit breeding by experiment stations in Canada and the United States. Until 25 or 30 years ago the vast majority of new varieties of fruits produced in North America came from fruit growers, both amateur and commercial, and from private fruit breeders. Since the turn of the century and particularly since about 1920 that situation has changed and publicly supported experiment stations have introduced large numbers of new varieties of fruits. Because so many stations are now engaged in fruit

breeding and additional ones are taking up the work each year it appeared worthwhile to make a survey of the field to find out how many are carrying on active research programs in fruit breeding, what fruits are involved, what have been the significant accomplishments and what we may expect to come out of this work in the next 5 years.

To assemble the required data it seemed necessary to resort to the traditional and ubiquitous questionaire. For this I hereby publicly apologize and at the same time express my heart-felt gratitude to my friends and associates who so graciously received and filled out the forms. The questionnaire was submitted to 118 federal, state, territorial, dominion and provincial stations in the two countries. In the United States an effort was made to reach branch stations that are engaged in research wtih fruits. Perhaps some were overlooked although no evidence that such was the case appeared in correspondence with central stations. The questionnaire was sent to all stations recorded in Canada. This report is based upon information from 92.4 per cent of all institutions contacted. Direct returns were received from 108 stations and one other was added on the basis of data available in published reports.

TABLE I—SUMMARY OF REPLIES TO QUESTIONNAIRE

	Canada	United States	Total
Questionnaires sent out	35	83	118
Questionnaires returned	31	78	109
Number of Stations with active breeding projects	17	53	70
Stations with breeding projects discontinued	2	14	16
Stations never engaged in fruit breeding	12	11	23

An examination of Table I discloses the fact that 70 experiment stations are engaged in fruit breeding. This is 59.3 per cent of all stations. The percentage will be even higher if any of the nine stations not reporting have fruit breeding projects. The per cent of participation is 48.6 per cent for Canadian stations and 63.9 per cent for those in the United States. Two stations in Canada and 14 in the United States have at some previous time had active projects which are now discontinued. Breeding work at these stations was dropped for various reasons, but change in personnel or general reorganization of research programs accounted for most cases. Only 23 stations of the 109 reported for the two countries have never initiated research in this field.

Because fruit breeding experiments are necessarily slow moving and of long duration it is important to know how long these 70 stations have been engaged in this research. Seven started priod to 1900 and, excepting one which dropped the work for a time, have been continuously engaged in fruit breeding for more than 50 years. On the other hand, six have organized projects only within the past 3 years. Between these extremes there occurred a steady and consistent development in both countries until 1930. At that time the influx of new stations taking up fruit breeding leveled off temporarily in Canada, but this was more than offset by accelerated activity in the United States where the number of stations engaged in fruit breeding has slightly more than doubled since that date. It will be noted in Table II and the

graph (Fig. 1) that during the 5-year period 1935 to 1939 in the United States 14 new stations began fruit breeding. This is more than 26 per cent of all the stations now engaged in fruit breeding in this

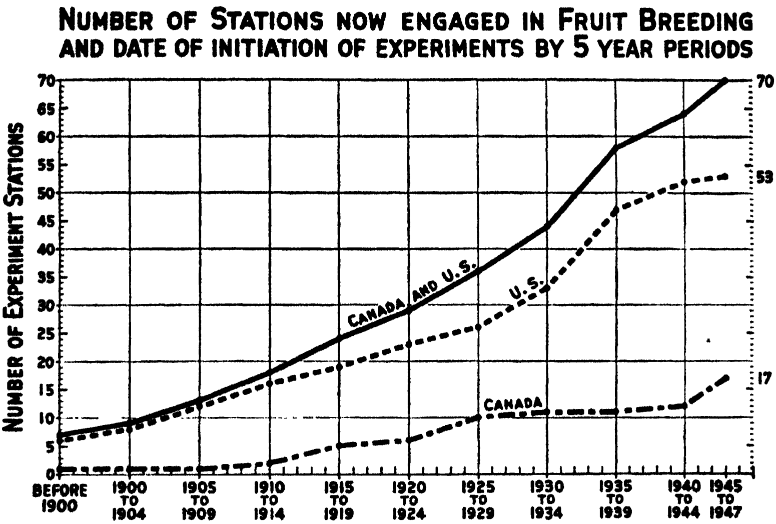

FIG. 1. Number of stations now engaged in fruit breeding and date of initiation of experiments by 5-year periods.

country. It will be recalled from Table I that 16 stations had at some time maintained programs in fruit breeding, but have now discontinued such work. Data concerning the periods when these projects were active is not available and those stations are not included in Table II or in the graph in Fig. 1.

TABLE II—NUMBER OF STATIONS NOW ENGAGED IN FRUIT BREEDING AND DATE OF INITIATION OF EXPERIMENTS BY FIVE YEAR PERIODS

Date Initiation	Number in Canada	Number in United States	Total Number
Prior to 1900	1	6	7
1900–1904	0	2	2
1904–1909	0	4	4
1910–1914	1	4	5
1915–1919	3	3	6
1920–1924	1	4	5
1925–1929	4	3	7
1930–1934	1	7	8
1935–1939	0	14	14
1940–1944	1	5	6
1945–1947	5	1	6
Totals	17	53	70

With fruit breeding research underway in 70 experiment stations in the United States and Canada it is to be expected that all major fruits and most of the minor ones would be involved. This proved to be true when the data from the questionnaires were tabulated. Table III lists

10 fruits or groups of fruits, each of which was included in a breeding program by 13 or more stations. In addition to these, 20 other fruits or groups of fruits were included in breeding programs by from one to nine stations each. In this miscellaneous class various citrus species were included in one group and several species of nuts in another. There were actually about 45 distinct kinds of fruits which were consolidated into 11 classes in Table III. The strawberry and the apple (including crabs) were decided favorites and were listed in the breeding programs of approximately 50 per cent of all the stations. These fruits dominate the field particularly in Canada, where out of 17 stations engaged in fruit breeding 15 are working with apples and crabs, and 12 with strawberries. In the United States the strawberry with 24 stations holds first position but it is closely followed by the peach and apple with 23 and 20 stations respectively. The number of stations working with a fruit does not indicate the importance of that fruit, but rather it is a measure of the interest of public institutions and their fruit-growing constituency in the possibilities of improving that fruit, or of adapting it to cultivation in areas where it is not now grown successfully. As an extreme example of the disproportionate relationship sometimes found between importance or value of fruits and breeding activities we find only three stations engaged in breeding citrus and 13 breeding blueberries. On the other hand, it is not surprising to find that such widely grown fruits as the strawberry and the apple are included in the breeding programs of 36 and 35 stations respectively.

TABLE III—FRUITS INVOLVED IN ACTIVE BREEDING PROJECTS AND NUMBER OF STATIONS WORKING WITH EACH

Variety	Canadian Stations	United States Stations	Total Stations
Apple and crab	15	20	35
Apricot	4	9	13
Blueberry	1	12	13
Cherry	8	10	18
Grape	4	16	20
Peach	3	23	26
Pear	5	14	19
Plum and Cherry-plum	9	12	21
Raspberry	6	16	22
Strawberry	12	24	36
20 miscellaneous fruits (1–9 stations each)	10	46	56
Totals	77	202	279

The diversity of fruit-breeding activities is well illustrated by Table III. If the work with each individual fruit by each station may be regarded as a separate project or enterprise, there are found to be 279 such projects in active operation in the two countries at the present time. But this only partially indicates the scope of the work. For instance, we find 35 stations working with the apple. Perhaps no two of these have the same objectives. Some are breeding for greater winter hardiness, some for late bloom, others are seeking disease resistance, annual production, better fruit adherence, better nutritive qualities, resistance to spray injury, improved tree type, or drouth resistance, to mention only a few of the characters involved in the breeding objectives of the various workers. Since similar situations prevail with other

fruits it is obvious that the fruit-breeding program in its entirety is not only comprehensive but enormously complex.

Up to this point the survey report has established the fact that a surprisingly large proportion of experiment stations in the United States and Canada are actively engaged in fruit breeding. Since some have been at it for over half a century and many for more than 20 years it seems highly desirable that an attempt should be made to render an accounting and evaluate accomplishments. This becomes particularly important in view of the fact that new stations constantly are entering this field and are adding to the volume of funds and personnel invested in fruit-breeding research.

In Table IV a summary is presented showing the total number of varieties of fruits introduced by all experiment stations which have been engaged in fruit breeding. This includes not only introductions from the stations that are now actively working in the field, but also 37 varieties from eight of the 16 stations which at one time or another were active in this field but have now discontinued fruit breeding. These introductions are grouped into three periods of uneven length. The first period covers the early work and includes introductions made prior to 1920. That date has come to be regarded as the beginning of a period of very active new variety introductions and was chosen by Brooks and Olmo as a suitable point at which to begin their very valuable register of new fruit and nut varieties. In this study it was thought desirable to break down the remaining 28 years, from 1920 to 1947 inclusive, into periods of 20 and 8 years respectively. This was done because in recent years stations have apparently adopted a more conservative policy and are subjecting their new productions to more rigid pre-introduction testing than was the case during the twenties and early thirties. During the last period it will be noted that only 221 varieties have been introduced, in spite of the fact that there has been a great increase in the number of stations now engaged in fruit breeding. Had the rate of introductions been the same for the period 1940 to 1947 as it was during the period 1920 to 1939 there would have been introduced in the past 8 years 325 varieties instead of 221. This change is particularly noticeable among Canadian stations. In explanation of this it should be stated that for a great many years the Central Experimental Farm at Ottawa had established a policy of naming the selections at the time they were distributed for test purposes and this naturally resulted in large numbers of introductions being recorded in the first and second periods in Table IV. A somewhat similar situation also prevailed at one time in the South Dakota Agricultural Experiment Station. As far as can be determined all stations in both countries are now identifying their selections by numbers or some similar code during the testing period and are attaching permanent names to their varieties only at the completion of a reasonably adequate testing program. Eight out of the 16 stations which have discontinued fruit breeding work contributed to the varietal introductions listed in Table IV. Of the 37 varieties which came from these stations one was introduced in the first period, 34 in the second period and two in the third or current period.

The last column of Table IV is of considerable interest because it gives a clue as to the number of new fruits that may be expected to be introduced in the next 5 years. It will be noted that the total anticipated introductions amount to 502 varieties, more than twice as many as were introduced in the period from 1940 to 1947 and approximately a third as many as have been introduced by all stations during the total period of fruit-breeding research in both countries. This total of 502 represents the best estimate that could be made by the workers in charge of the breeding investigations in 70 stations. In studying the individual estimates it seemed clear that the older breeders were very conservative and that, in general, optimism prevailed among the workers with recently organized breeding programs. In all cases where the worker allowed a range in his estimate, the lowest number was used in the tabulation. Some very conservative workers refused to commit themselves with any estimate even though past history of their particular breeding project would strongly suggest a likelihood of introductions within the next 5 years. Upon the whole it is believed that these estimates should be taken seriously and that an ultra-conservative estimate would reduce the number by not more than 10 or 20 per cent. It seems reasonably certain that between 400 and 500 new varieties of fruits will be introduced in the next 5 years.

TABLE IV—Number of Fruit Varieties Introduced by Experiment Stations in the United States and Canada

	Prior to 1920	1920 to 1939	1940 to 1947	Total	Anticipated 1948 to 1952
Canada	321	360	66	747	131
United States	178	454	155	787	371
Total	499	814	221	1,534	502

The fact that 1,534 varieties of fruits have been developed and introduced by experiment stations is worth recording because of its historic interest but the 64 dollar question is not how many were introduced, but rather how many have demonstrated significant value to North American horticulture. To shed light upon this important subject, fruit breeders were asked to evaluate the introductions from their own stations and to indicate the number of varieties which have stood the test of time and are today recognized as being of significant horticultural importance. Table V, containing a summary of replies to this question, is in itself a magnificent tribute to the candid honesty and conservatism of our fruit breeders. It will be noted that out of the 499 varieties introduced prior to 1920 only 62 or 12.4 per cent have sur-

TABLE V—Number and Per Cent of Introduced Varieties Which Are Considered Horticulturally Important in 1947

	Prior to 1920		1920 to 1939		1940 to 1947		Total	
	Number	Per Cent	Number	Per Cent	Number	Per Cent	Number	Per Cent
Canada	22	6.9	48	13.3	23	34.9	93	12.5
United States	40	22.5	186	41.0	76	49.0	302	38.3
Total	62	12.4	234	28.7	99	44.8	395	25.8

vived the acid test and are today recognized as being of horticultural importance. In the next period, 1920 and 1939 inclusive, 234 representing 28.7 per cent of those introduced have made good and are recognized as important varieties at the present time.

In assessing the value of the more recent introductions during the current period of 1940 to 1947 the breeders exhibited varying points of view. Some felt that because these new fruits had been out such a short period of time it was impossible to evaluate their impact upon the horticultural industry. A few took the attitude that because these varieties were considered of significant horticultural value at the time of their introduction they should be listed as important varieties until there is conclusive evidence of failure. Between these two extremes were found most of the fruit breeders who did make a serious effort to differentiate the mediocre from the good among these recent introductions. It will be noted that they designated 99 out of a total of 221 recent introductions as being of horticultural importance. Out of the grand total of 1,534 varieties introduced by all experiment stations 25.8 per cent have made a place for themselves in American horticulture. If we contrast the percentage of Canadian introductions which have been made good with those which have enjoyed similar success from stations in the United States it will be found that the Canadian score is relatively low. This is by no means a reflection upon the success of fruit breeding in Canada but it is the unavoidable result of their early policy of attaching names to their selections when these were distributed for trial purposes. In both the United States and in Canada there is exhibited a most encouraging and significant trend in the consistently increasing percentage of varieties which have made good in the successive periods.

TABLE VI—FRUITS INTRODUCED BY KINDS AND PERIODS

Variety	Prior to 1920	1920 to 1939	1940 to 1947	Total	Anticipated 1947 to 1952
Apple and crab	340	279	35	654	99
Apricot	—	14	9	23	16
Blueberry	—	16	3	19	22
Cherry	—	27	7	34	25
Grape	6	71	31	108	39
Peach	—	50	34	84	63
Pear	10	30	7	47	17
Plum and Cherry-plum	21	65	16	102	34
Raspberry	21	44	6	71	39
Strawberry	32	109	43	184	67
Miscellaneous	69	109	30	208	81
Total	499	814	221	1,534	502

Fruit breeders who today are working with some 45 different kinds of fruit will be interested in the number and kinds of varieties which have been introduced to date and those which are likely to be introduced in the next 5 years. It is not feasible, within the limits of this paper to show a break-down of all 45 kinds. In Table VI, however, this information is given for 11 fruits or groups of fruits following the same classification as was used in Table III. A striking feature of Table VI is the extraordinarily large number of introductions of apples and crabs, which make up nearly 43 per cent of the total num-

ber of all kinds of fruits introduced. The disproportionate number in this category is explained by the previously mentioned Canadian policy of giving their selections varietal names during the test period. The extensive and early work of Saunders and Macoun at the Central Experimental Farm at Ottawa resulted in the distribution of over 400 named selections of apples, crabs and crab hybrids during the first and second periods of this survey. Had these been tested under code numbers no more than 10 or 15 per cent would have received names. This would have reduced the total number of apple and crab introductions to 300 or less but that group would have still remained the largest by a wide margin. Following the apple other groups showing large numbers of introduced varieties are, in order, strawberry, grape, plum, peach and raspberry. These same fruits lead all others in anticipated introductions in the next 5 years. It is of interest to note that a large number of peach varieties are expected and that this fruit will be making a close race with the strawberry for second place.

How deep an imprint have these new varieties made on the fruit industries of North America and how important are they from the standpoint of future development of the fruit industries? These two questions are difficult to answer because of lack of precise information regarding the volume and extent of planting and because evaluation of their importance must be based largely upon personal judgements and opinions which would vary widely between individuals. Possibly it is both foolhardy and futile to attempt answers to these questions in other than very general terms. In evaluating the importance of a fruit variety the time element is highly important because change of varieties in commercial fruit plantings take place very slowly. Perhaps only with the strawberry do varieties wax and wane with a speed comparable to that of agronomic crops. The best known and the most widely grown American apple today is the Delicious. The speed with which this variety acquired its present fame is considered quite phenomenal, but it was promoted by a modern advertising campaign, such as no other variety of fruit in the world has ever enjoyed. How long did it take under such favorable circumstances? It was introduced a little over 50 years ago.

In this survey the fruit breeders have indicated that 395 varieties introduced by experiment stations are of some horticultural importance, but actually it is still too early for the great majority of these introductions to have attained their full significance. In spite of the limitations of time, however, and without excessive advertising some of these introductions have attained considerable prominence in American horticulture. A few will be mentioned which have received rather widespread acceptance. It was stated in the 1937 Yearbook of Agriculture that 20,000 acres of Blakemore and Dorset strawberries were under cultivation in the United States. This was approximately 10 per cent of the total acreage of strawberries grown at that time. At about that same time it was announced that the acreage of Latham red raspberry grown in North America was greater than that of all other red raspberry varieties combined. The Newburgh red raspberry has also been very widely planted. The youthful, but very vigorous industry in

cultivated blueberries, is based almost entirely upon varieties introduced by experiment stations. The Red Lake currant is credited with being the most popular variety of red currant in America. The Cortland apple, although not of major importance, is widely grown in both the United States and Canada. In the citrus industry the improved strains of orange, grapefruit and lemon developed by bud selection have made a profound impression and trees propagated from these superior strains run into the millions. An interesting situation prevails in the peach industry which illustrates the tenacity with which an established variety of mediocre quality may dominate an industry. In recent years peach breeders have produced many varieties seemingly far superior to the Elberta. How long it will take some of these newer and better varieties to dethrone the present queen remains a matter of conjecture but it looks as though the throne is tottering. And so we might continue to point out introduction after introduction that have become highly significant in local areas but it seems unnecessary to prolong the discussion of this point.

In considering the importance of experiment station introductions one must recognize values outside the commercial field. There is a great area in North Central United States and in Canada where climatic conditions have made fruit growing difficult. Fruit breeding by experiment stations in this region has developed many varieties involving a wide range of fruits which are especially adapted to home orchards and gardens in this non-commercial area. The importance of such varieties cannot be measured in dollars and cents. Nevertheless, the valuation is high because it is measured in terms of better living, improved diet and greater satisfaction and enjoyment of life by the millions of citizens who populate this region, a region equivalent in size to about one half the area of the United States.

What is to be the future of fruit breeding in North America? This survey has indicated surprisingly widespread activity in this field among the experiment stations of this continent. A rapidly mounting interest in the extension of this type of research in these institutions is also apparent. Changing fashions is a phenomenon not confined to women's hats. We have seen it also in horticultural research. Many of us can recall that from about 1910 to 1920 there was intense interest in the application of the science of plant physiology to the problems of the fruit grower. The horticultural department of that time which did not have some high-powered project in that field was considered behind the times and out of step with modern thought in research methods. A little later came the science of biometry and for a few years reports of horticultural research seemed to contain more mathematics than horticulture. Of course plant physiology and statistical analysis are highly important and efficient tools for use in productive horticultural research and now are widely used in that capacity by horticulturists. We may wonder if the present activity in fruit breeding is merely another mounting fashion that may soon change, or is it the expression of a more permanent and lasting interest? There are at least two reasons for believing the latter to be the case. First there has been no sudden flare-up of interest in fruit breeding research, but

rather it has steadily grown and expanded for a period of 50 years or more. Second, because of their genetic constitution, fruits are difficult materials for use in genetic studies and fruit breeders, in the main, are not likely to become diverted from the objective of producing better fruits to that of advancing genetic science. On the other hand, however, there is unquestionably a trend among fruit breeders to make more extensive and efficient use of genetic science as a tool to be used in their breeding programs.

If we may assume that the present intense interest and activity in fruit breeding research will continue and may even be increased, is it possible at this time to predict some of the future trends and developments in this field? The answer is yes, for certain of these trends are already beginnig to be well defined and recognized. In conclusion some of these will be briefly noted.

Local Adaptability

In a region as large as the United States and Canada there is a great range in soil and climatic conditions and fruit breeders have already gone a long way toward producing varieties adapted to the varying environments. In recent years they have become increasingly conscious of the degree to which localization of adaptability may be involved even within a state or province. The broad aspects of this problem may be visualized by reference to the breeding program with the apple in these countries. Thirty-five stations are working with this fruit and these are fairly well distributed over the area from Los Angeles, California to Fredericton, New Brunswick and from State College, Mississippi to Beaver Lodge, Alberta. Each station is working either to produce better varieties than those now grown in their locality or to extend the previous range of apple production. In all cases the primary aspect of the problem is local adaptability.

Temperature Conditions

For many years nearly all northern fruit breeders and many of those farther south have been breeding for greater winter hardiness. As plant physiologists have come to understand better the fundamentals of winter hardiness they have presented a new problem to the plant breeder, or perhaps it would be more accurate to say a new avenue of approach to an old problem. The situation in the Latham red raspberry will illustrate this point. Under conditions of steady cold this variety will endure winter temperatures of —50 degrees F. Unfortunately, dormancy is easily broken by short periods of warm winter temperature and this is accompanied by growth activity and loss of cold resistance. When this occurs, the variety is often badly injured by subsequent cold temperatures of only moderate intensity. The raspberry breeder is now confronted with the problems of both cold resistance and prolongation or maintenance of dormancy. Peach breeders in the deep South are concerned with a similar problem in reverse where they must work toward varieties with a less intense rest period which may be broken with a minimum of cold. With some fruits and in some

localities blossom injury from late spring frosts is a serious matter. Breeders are attacking this problem from two angles, the production of later blooming varieties and the development of varieties with increased cold resistance in the flowers. Breeding problems with respect to temperature relations are now recognized as almost universal and will occupy an important place in future fruit breeding programs.

Disease and Insect Resistance

Sufficient progress has already been made in breeding for disease resistance to indicate that this may become one of the most important features of future breeding. With definite evidence established that a high degree of resistance or even immunity can be achieved for all classes of diseases — fungous, bacterial and virus — there is every inducement for breeders to expand and intensify their work in this direction. With some fruit and certain diseases it may take a long time to combine resistance and other horticultural qualities which are essential if a variety is to be utilized by the fruit industry. The value and importance of such a variety, however, will be great enough to justify the costly and time-consuming research that will go into its development. In the field of insect resistance the picture is not so clear but a modest beginning has been made and the progress, though limited, offers a definite ray of hope for future achievements.

Quality

Better dessert, culinary or shipping qualities commonly have been set-up as goals in most fruit breeding enterprises. These will continue to be important objectives but they will be broadened to include a more critical examination of nutritive qualities and, particularly, those associated with vitamin content. Differences between varieties with respect to processing qualities long have been recognized but the recent development of the frozen food industry has focused attention upon the lack of adaptability of many standard varieties to freezing for either home or commercial use. Already breeding programs with some fruits have been altered to include the definite objective of improvement in quality for freezing purposes. It seems certain that the need for the fruit industry to establish new market outlets through various processing channels will have a profound bearing on the trend of future breeding operations.

Reliability

Fruit growing is becoming a highly competitive industry and the commercial fruit grower is becoming very sensitive to production costs. It is possible that the fruit breeder may contribute substantially toward lowering costs of production. For instance, a productive variety of apple with an annual bearing habit would lower production costs by removing the all too common "off year" when maintenance expenses must be carried without compensating income return. Apple breeders have already produced such varieties of satisfactory market quality and appearance. Furthermore such varieties rarely put on an

overload and seldom require thinning thus eliminating another production cost. Breeders also have produced varieties that adhere well to the tree at harvest time. This feature also will lower production costs by avoiding excessive loss through wind-falls and by removing the necessity for a harvest-drop spray. Varieties have been produced that combine all these characteristics making for reliability of production but it has not yet been demonstrated that such varieties are adapted to more than limited localities. Such accomplishments, however, do indicate that it is possible for apple breeders to produce for any locality varieties that are consistently reliable producers of annual crops. What is being done with the apple is indicative of what may be done with other fruits. Fruit breeders are conscious of this situation and a definite trend towards breeding for reliability of production is manifest.

Critical Pre-Introduction Testing

In conclusion your attention is called to an important trend which is already so well defined that it needs little amplification. Within the last 15 or 20 years practically all experiment stations engaged in fruit breeding have made serious efforts to test their varieties more thoroughly before introducing them to the public. Adequate pre-introduction testing is not only one of the most important but it is also one of the most difficult problems connected with fruit breeding. It is most encouraging to note the development of a conservative attitude on the part of fruit breeders for it indicates that both individuals and institutions are recognizing and assuming the responsibility that is associated with the introduction of a new variety of fruit. If the variety in question is likely to enter into commercial production in a major fruit industry, this responsibility is indeed heavy. It is true that the ultimate test of any new variety rests with the growers but unless the fruit breeder has subjected this variety to as complete a testing program as his facilities will permit he is depriving his fruit-grower friends of a service they have a right to expect and is shirking his responsibilities as a public servant.

LIST OF EXPERIMENT STATIONS IN CANADA AND THE UNITED STATES MAINTAINING ACTIVE PROJECTS IN FRUIT BREEDING AND FRUITS INVOLVED IN THESE PROJECTS

United States State Experiment Stations

Alabama, Auburn— Agricultural Experiment Station	Collecting and testing native material and chance seedlings. Apple, cherry, grape, peach, pear, plum, raspberry, strawberry, blueberry, pecan, walnut, pomegranate.
Arkansas, Fayetteville— Agricultural Experiment Station	Apple, grape, peach, strawberry.
California, Davis— Agricultural Experiment Station	Almond, apricot, blackberry, nectarine, peach, pear, plum, raspberry, sweet cherry, strawberry.
California, Los Angeles— Agricultural Experiment Station	Apple, avocado, cherimoya, feijon, white sapote.
California, Riverside— Citrus Experiment Station	Avocado, citrus, peach.
Florida, Homestead— Sub-Tropical Experiment Station	Avocado, guava, papaya.
Georgia, Experiment— Agricultural Experiment Station	Grape.
Georgia, Tifton— Coastal Plain Experiment Station	Blueberry.

Hawaii, Honolulu— University of Hawaii Agricultural Experiment Station	Avocado, macadamia, mango, papaya.
Idaho, Moscow— Agricultural Experiment Station	Sweet cherry.
Illinois, Urbana— Agricultural Experiment Station	Apple, blackberry, cherry, currant, gooseberry, peach, pear, pecan, persimmon, plum, raspberry, strawberry.
Indiana, LaFayette— Agricultural Experiment Station	Apple (scab resistance).
Iowa, Ames— Agricultural Experiment Station	Apple, peach, pear, plum, raspberry, strawberry.
Louisiana, Baton Rouge— Agricultural Experiment Station	Peach, strawberry.
Louisiana, Hammond— Fruit and Truck Station	Blueberry, strawberry.
Maine, Orono— Agricultural Experiment Station	Apple, strawberry.
Maryland, College Park— Agricultural Experiment Station	Peach, raspberry, strawberry.
Michigan, East Lansing— Agricultural Experiment Station	Apple, apricot, blueberry, cherry, peach.
Michigan, South Haven— South Haven Horticultural Experiment Station	Blueberry, peach.
Minnesota, St. Paul— Agricultural Experiment Station	Apple, apricot, cherry, currant, grape, gooseberry, hazelnut, highbush cranberry, Juneberry, peach, pear, plum, raspberry, strawberry.
Mississippi, State College— Agricultural Experiment Station	Apple, plum.
Missouri, Columbia— Agricultural Experiment Station	Apple, grape, strawberry.
Missouri, Mountain Grove— Fruit Experiment Station	Apple, grape, peach, pear, plum, strawberry.
New Jersry, New Brunswick— Agricultural Experiment Station	Apple, blackberry, nectarine, peach.
New Hampshire, Durham— Agricultural Experiment Station	Apple, blackberry, blueberry, peach, pear, raspberry.
New York, Geneva— Agricultural Experiment Station	Apple, apricot, blackberry, cherry, gooseberry, grape, nectarine, peach, pear, plum, raspberry, strawberry.
North Carolina, Raleigh— Agricultural Experiment Station	Blackberry, blueberry, grape, raspberry, strawberry.
North Dakota, Fargo, State College— Agricultural Experiment Station	Apricot.
Ohio, Wooster— Agricultural Experiment Station	Apple.
Oklahoma, Stillwater— Agricultural Experiment Station	Apple, grape, nectarine, peach, pecan.
Oregon, Corvallis— Agricultural Experiment Station	Blackberry, cherry, peach, pear, raspberry, strawberry.
Oregon, Medford— Southern Oregon Branch Station	Pears.
Pennsylvania, State College— Agricultural Experiment Station	Raspberry.
South Carolina, Clemson— Agricultural Experiment Station	Blueberry, grape.
South Dakota, Brookings— Agricultural Experiment Station	Apple, apricot, cherry, grape, pear, plum, raspberry.
Tennessee, Knoxville Agricultural Experiment Station	Blackberry, pear, raspberry, strawberry.
Texas, College Station— Agricultural Experiment Station	Blackberry, citrus, peach.
Utah, Logan Agricultural Experiment Station	Apricot, cherry, peach, raspberry, strawberry.
Vermont, Burlington— Agricultural Experiment Station	Strawberry.
Virginia, Blacksburg— Agricultural Experiment Station	Apple, grape, nectarine, peach, raspberry.
Washington, Pullman— Agricultural Experiment Station	Apricot, peach.
Washington, Puyallup— Western Washington Experiment Station	Raspberry, strawberry.
Washington, Long Beach— Cranberry Blueberry Laboratory	Blueberry, cranberry.
West Virginia, Morgantown— Agricultural Experiment Station	Blueberry.
Wisconsin, Madison Agricultural Experiment Station	Strawberry.

United States Federal Experiment Stations

California, Fresno— United States Horticultural Field Station	Grapes.
Florida, Orlando— United States Sub-tropical Fruit Field Station	Citrus species, papaya.
Georgia, Fort Valley— United States Horticultural Field Laboratory	Peach.
Maryland, Beltsville— Plant Industry Station	Apple, blackberry, blueberry, cherry, cranberry, grape, peach, pear, plum, raspberry, strawberry.
Mississippi, Meridian— United States Horticultural Field Station	Grape.
North Dakota, Mandan— Northern Great Plains Field Station	Apple, currant, gobseberry, Juneberry, pear, plum.
Oklahoma, Woodard— Southern Great Plains Field Station	Apricot, grape, peach.
Wyoming, Cheyenne— Cheyenne Horticultural Field Station	Raspberry, strawberry.

Canadian Experiment Stations

Alberta, Beaverlodge— Agricultural Experiment Station	Apple, Juneberry.
Alberta, Brooks— Providence Horticultural Station	Apple, apricot, cherry, pear, plum.
Alberta, Edmonton— University of Alberta	Apple, strawberry.
British Columbia, Agassiz— Dominion Experiment Farm	Raspberry, strawberry.
British Columbia, Prince George— Dominion Experiment Station	Apple, blueberry, cherry, plum, raspberry, strawberry.
British Columbia, Saanichton— Dominion Experiment Station	Apple, strawberry.
British Columbia, Summerland— Dominion Experiment Station	Apple, apricot, cherry, peach.
Manitoba, Morden— Dominion Experiment Station	Actinidia, apple, apricot, cherry, currant, gooseberry, grape, lonicera villosa, plum, raspberry, strawberry.
Manitoba, Winnipeg University of Manitoba	Strawberry.
New Brunswick, Fredericton— Dominion Experiment Station	Apple, strawberry.
Novia Scotia, Kentville— Dominion Experiment Station	Apple, strawberry.
Ontario, Ottawa— Central Experiment Farm	Apple, cherry, currant, gooseberry, grape, highbush cranberry, nuts, pear, plum, raspberry, strawberry.
Ontario, Vineland Station— Horticultural Experiment Station	Apple, cherry, grape, peach, pear, plum, raspberry, strawberry.
Quebec, Ste. Anne de la Pocatiere— Dominion Experiment Station	Apple, strawberry.
Saskatchewan, Saskatoon— University of Saskatoon	Apple, cherry, gooseberry, grape, pear, plum, raspberry, strawberry.
Saskatchewan, Scott— Dominion Experiment Station	Apple, plum.
Saskatchewan, Sutherland— Dominion Forest Nursery Station	Apple, apricot, cherry, peach, pear, plum.

Horticulture in Science and Society

(Presidential Address)

By H. B. Tukey, *Michigan State College, East Lansing, Mich.*

Each year the President of the American Society for Horticultural Science is called upon to deliver an address before the annual meeting. The assignment is neither by courtesy nor through tradition. No, indeed! The Society has written into the By-Laws the charge to the President that one of his duties shall be to "deliver an address at the regular annual meeting".

Quite naturally, in preparation for such an address, a man reviews the remarks that have been made on similar occasions. And when he does so, he cannot fail to notice that they have seemingly dealt with problems that were uppermost at the moment.

For example, in 1904, in the formative years of the Society, Liberty Hyde Bailey attempted to answer the question, "What is Horticulture?" (1) and then followed with remarks on research in horticulture. In turn, various presidents analyzed research methods and the spirit and philosophy of research as the new Society grew and developed, and as research in the field of horticulture grew and developed. Then came a time when there was sufficient perspective to discuss the historical eras of development in horticulture (18). Still later it seemed worthwhile to re-examine the Society to see what it as an organization had done and what its course should be (21). Then, in keeping with the times, the emphasis shifted to moral responsibilities of research workers (34) and to the scientific method as a tool for social problems (35). Still more recently, as research has again gotten back into stride, have come surveys of research projects under way in horticulture in the country (39) and the applications of scientific methods to modern research (40).

These addresses have so impressed me (1–40) that I should like to commend to you an evening spent with them, and that they be used in the classroom as background material for those entering upon horticultural research or teaching.

Questions That Confront Horticulturists Today

Now, we come to the year 1947, and I find myself in turn apparently doing what my predecessors have done, namely, revolving in my mind some of the questions and problems which confront us today.

First of all, following the gigantic upheaval of World War II, we are faced with a re-evaluation or re-appraisal of "What is horticulture?", "What is a horticulturist?", because on the one hand we find ourselves approached by a group of biologists asking for our moral and material support in an organization known as "The American Institute of Biological Sciences". Are we biologists? On the other hand, we are approached by a group who would draw together all those who are interested in horticulture — in all its phases, with emphasis on the amateur spirit — to form a "United Horticulture" under the leader-

ship of the "American Horticultural Council". Are we amateur horticulturists?

We are asked to show our allegiance to what is called fundamental or "pure" science on the one hand (as though there were "impure" science), and to practical problems, on the other, which are of such an order as to be no more than service work. Are we scientists? Are we practitioners?

Again, we hear the warnings: "You horticulturists are losing out. The agronomists are taking over soils. The economists are taking over consumer-packaging and marketing. You will have nothing left". Are we neglecting our field?

And, finally, to cap the climax, when an appropriation is sought from the State legislature for research in *horticulture*, the reception is cool. But, when the approach is for research in *fruits, vegetables, flowers, nursery crops, processing,* and *utilization,* the comment from the same legislative group is: "Why, certainly we are interested. Why didn't you say this in the first place? You said 'horticulture' ".

And so, all in all, the time seems ripe for a look at some of these questions, to see whether we can arrive at reasonable answers and be guided by them.

WHAT IS HORTICULTURE? WHAT IS A HORTICULTURIST?

First, then, what is horticulture as we think of it today? What is a horticulturist? Originally, it meant the cultivation of a garden. Those plants which were cultivated in gardens or in more intensive type of plant growing acquired the name of "horticultural plants" in contrast to the culture of field crops. This has meant flowers, fruits, vegetables, ornamentals, and sometimes herbs and medicinal plants. It represents a certain refinement of agriculture, some of which comes with leisure and which is associated with home. I accept this general viewpoint as "horticulture", and the one who operates in this field as a "horticulturist".

In England, if the remarks of the Royal Horticultural Society may be taken as representative, horticulture is differently proportioned than it is in America (14). There, it is "a definite craft of itself and is not a department of agriculture. As differentiated from agriculture, it includes the more intensive cultivation, as usually practiced in gardens, of fruits, vegetables, flowers, and ornamental trees". It is thought of as coordinate with agriculture, but as distinct from it as is forestry. The time has not yet arrived in this country when this separation is either necessary or desirable, but it could come about if we were to drift away from the basic conception of horticulture and leave it abandoned to others.

Horticulture is also a point of view; a field of thinking, of activity, of operations; a rallying point. This is more clearly seen in the classroom and in teaching. Less time is now required from students in the study of so-called "horticulture" than in the earlier days, especially from advanced students. More and more they are sent into plant physiology, morphology, genetics, mathematics, entomology, geology, physics, economics, chemistry, and other fields for basic knowledge.

But the seminar, the library, the reading room, and the correlating horticultural courses are still retained as the rallying points to which the students return.

And as they return they think in terms of cabbages, carrots, camellias, canned goods, apples, and nursery stock. Once more as they go to the basic fields, it is hoped that they may think in terms of onions as they study genetics, in terms of keeping quality of apples as they study respiration, in terms of tender peas as they study gametophytes and fruit development, and of supplying citrus as they study economics. In all of this, a student in horticulture may drift away so far as to become a chemist or a physicist. In this there is no harm, but it must be recognized that it is the point of view of the individual that has shifted. Horticulture still remains.

The Liaison Function in Horticulture

As horticulture operates after this fashion it serves an important function. It has tended to draw distant fields together, as chemistry, genetics, physics, and morphology. The activities of the American Society for Horticultural Science illustrate the point. A look back over the programs of the Society is impressive in both the number and the diversity of the joint sessions which have been held. A number of years ago the Society was instrumental in drawing together the plant physiologists, at another time the statisticians, the geneticists, and the plant breeders. At the moment it is concerned with drawing closer to workers in processing and food technology, and to those in soils, fertilizers, and nutrition. It should meet jointly with the American Society of Agronomy.

But if horticulture must reach out into these fields in this way, does this mean that it is losing out? Does it mean that nutritional disorders will be taken over by soil science just as insect and disease control have been taken over largely by entomology and pathology? The fear is often expressed that if this continues, there will be no horticulture left.

The facts are all to the contrary. There will always be horticulture, and so long as horticulturists work, and work with industry and intelligence, there is nothing to fear. If those in chemistry can be induced to work on horticultural crops, well and good. If agronomists and soil physicists can be attracted, so much the better. The concern should not be to keep horticultural crops solely for horticulturists. There might well be not only concern but alarm if this were so. The horticulturist should say of another man, or field, or department: "I do not care what you work on so long as it is a *horticultural* problem". He should serve as a liaison officer and seek out those who will help in their solution. Horticulture does not belong exclusively to Departments of Horticulture any more than stars belong exclusively to astronomers. There were stars long before there were astronomers, and there was horticulture long before there were professional horticulturists.

In all of this, generosity is a virtue. It should be cultivated. And the further horticulture is projected into these various fields, the greater service is performed. As the projection becomes more distant and

thinner, it may break off and be picked up by some passing sun. But what does it matter? The aim is not to build prestige or acquire wealth, but to give as excellent professional service as possible. If horticulturists operate in this way, they will serve horticulture best. Like a stone dropped into a pool, they will send waves outward in ever-widening circles until they become so small that they no longer register or are absorbed by other objects or forces. But the pool and the center of projection is still there.

Because, as Liberty Hyde Bailey well said in 1904, "I doubt whether the term horticulturist will long persist in highly developed schemes of education and investigation. There will be fruit-growing horticulturists, flower-growing horticulturists, nursery-growing horticulturists, and others" (1). And to this might be added the thought that there are already plant-breeding horticulturists, cytogenetic, nutritional, and others. To be sure the horticulturist may specialize to such a degree that he becomes not a cytogenetic horticulturist, but a horticultural cytogeneticist, and finally perhaps a cytogeneticist. But why not?

Hamor (51) has stated the situation in broader terms: "Scientific education and investigation, with unavoidable increasing sub-divisions, would become more satisfactory as means of human progress by linkage with a broad survey of very complex science in its entirety . . . . . the field in which each research man is located, would appear to him, not as an isolated region, but as a part of an aggregate". Horticulture serves such a purpose.

The Biological or Science Side of Horticulture

Our Society is called "The American Society for Horticultural Science", and its object is given "to promote the science of horticulture". It may be assumed that the expression "science of" really means to convey the thought of "science in", "scientific aspects of", the "science part of", as distinguished from "the science, comma, horticulture". There is a collection of scientific knowledge that may be called horticultural. And there are phases of chemistry, physics, mathematics, and biology which come within a sphere, which when set together are thought of as horticultural science. But to attempt to catalog the broad field of horticulture as a science in itself is not necessary. In fact, it may tend to develop the feeling that horticulture is sufficient unto itself. Those in this organization are largely horticultural scientists working in the science phase of horticulture. The outlook should be broad and constantly broadened, and not narrowed by a feeling independence or completeness.

Now, if the central core of this science be examined, it is found be biology. This is bound to be the case because horticulture deals with plants. Though they be special plants, they still have great significance and importance to human life. As Sinnott (54) states the case: "Plants have a monopoly on the synthesis of those materials which are of primary importance to life. They hold the basic patents of the organic world. The synthesis of carbohydrates, amino acids, and vitamins belong almost entirely to them. . . . As the groves were man's

first temple, so were they his first chemical laboratories". Or, as Robbins states it: "Photosynthesis is the most important, single chemical process in the world today". This, then, is the sort of thing with which we are dealing.

One need but look at the *Proceedings of the American Society for Horticultural Science* to appreciate this fact. Biology is the central core throughout — shading, polyploidy, the C/N relationship, developmental morphology, bulbs, flowers, vegetable crops, anatomy, genetics, flowering, rooting, abscission, stock and scion relations, hydroponics, mineral deficiencies, nutrition, photoperiod, storage, respiration, chimeras, embryo culture, vitamins, antibiotics, sprouting, weed control, and growth regulators. One need but visit the hothouse tomato industry to see plant physiology in practice, with operations on the "dry side" during dark days, more moisture on bright days, and nice balance between nitrogen, moisture carbohydrates, and sunshine. And if we will review history, we will see that the greatest contributions in the field of horticulture have been in the plant sciences. In fact, there are those who would say that the most important contributions to the plant sciences have been made by those working in the fields of horticulture and of agronomic crops. Be that as it may, horticulture is not marketing in itself, not soils, not transportation. It is fundamentally biology, though it may find expression in all the fields mentioned.

The Affairs Side of Horticulture

This brings us to another aspect of horticulture, namely, the business phase, or what Dr. Bailey has called "the affairs side". That is, besides the biological or science side there is a side which deals with human food, the economy of a civilization, the rearing and sale of plants, the manufacture of horticultural products.

We need dwell but briefly on this aspect. It has been well expressed elsewhere by others. The acreage of horticultural crops in America reaches hundreds of thousands. The money value reaches billions. Moreover, both the acreages and the values of these crops are increasing — not only in total amounts, but also in percentages of the whole.

The value of these crops to human nutrition is of added importance (53). Over 90 per cent of the total quantity of ascorbic acid and about 60 per cent of the total quantity of vitamin A is furnished by fruits and vegetables (48). In fact, the most notable change in food consumption in the United States between 1909 and 1945 has been the upward trend for dairy products (excepting butter), citrus fruit, and leafy, green, and yellow vegetables, and the downward trend in potatoes and grain products.

As civilization advances, horticulture is bound to advance, and in greater proportion than some other lines. The staples may move along proportionate to population changes, but horticultural products are dependent upon the attainment of better living, and the growth of ideals, for "refinement of civilization is marked by the transfer of articles from the class of occasional luxuries to the class of essentials" (1). And so progress in horticulture is closely identified with the economy of civilization and the attainment of an ever higher standard of living.

And this brings us logically to the "art or home side" of horticulture involving the love of plants, the love of gardens, and the use of plants to heighten beauty.

The Art and Home Side of Horticulture

It is this art and home side that at the moment is crying for attention and which is being pushed aside by too many. We become so involved in the biological and the affairs side that we overlook the one that is likely to be the most important in the years immediately ahead. As Dr. Crow said before this society in 1918 (14): "..... horticultural science could make no greater mistake than to underestimate the importance of horticulture at large to the amateur and his special interests".

Abraham Cowley (49) in his essay on "The Garden" explained the esteem in which gardening should be held by reminding us that: "The three first men in the world were a gardener, a ploughman, and a grazier; and if any man object, that the second of these was a Murtherer, I desire he would consider, that as soon as he was so, he quitted our Profession, and turn'd Builder".

Or the remarks of Francis Bacon (43): "God Almighty first planted a garden; and indeed it is the purest of human pleasures. It is the greatest refinement of the spirits of man, without which buildings and palaces are but gross handiworks; and a man shall ever see that when ages grow to civility and elegency, men come to build stately, sooner than to garden finely, as if gardening were the greater perfection".

L. H. Bailey has written: "Every generation sees some great addition to the depth and meaning of the home .... Every perfect home has its library; so in turn it must have its garden — a room, perhaps out-of-doors, in which plants grow.....One third of our city and village improvement is horticulture. Another third is architecture; and the other third is common cleanliness and decency".

Dr. W. H. Camp (47) tells us that gardening began 20,000 years ago when man first used cultivated plants for food. Many of these plants, remained as a matter of sentiment, or because they had become associated with religious ceremonies. Tulips, hyacinths, narcissus, Star-of-Bethlehem were first used as bulbous crops, like onions and garlic. Others had medicinal properties, as foxglove *(Digitalis purpurea)* from which is derived digitalis; and sweet scabious *(Scabiosa atropurpurea)* which was used as a cure for the itch. Rosemary, sage, lavender, and many mints were valued as herb plants. The root of elecampane was used as a tonic. Its age is indicated by its name, which is a corruption of the Roman *inula campana.* The garden pyrethrum *(Chrysanthemum coccineum)* is closely related to the source of the insecticide, pyrethrum, derived from the dried heads of *C. cinerariaefolium,* used to rub on the body for lice and fleas.

Perfume, too, had its value, as a substitute for soap and water in times when baths were less frequent. The sweet-scented, orris root was used as a dusting powder. Rose petals, lilac, lily-of-the-valley, — how many of the fragrances we value have come from flowers. The

dye, saffron, is from *Crocus sativus.* The drug colchicine is from a species of crocus.

According to Dr. Camp, the garden began its entry into the home when the early Egyptians painted scenes on walls and floors. The cooler winters of Persia brought these scenes indoors woven into rugs and wall tapestries. The Romans put them on wall paper. And so, many of our wall paper, rug and tapestry designs trace directly back to the garden, through the Romans, the Persians, and the Egyptians. It is worth noting that of 25,000 species of plants which are cultivated, about 10,000 are cherished for their ornamental value as flowers.

The Japanese and Chinese dwarf trees and potted plants are but attempts at copying extensive royal gardens in miniature. Or, as Dr. Camp puts it, the garden in a fishbowl is a direct lineal descendant of Chinese gardens which Marco Polo saw; of Indian gardens in which Gautama (the founder of Buddhism) preached; of the royal game preserve and hunting park which already were common in Mesopotamia when Abraham left Ur of the Chaldees to go over into the land of Canaan. The fish bowl garden is therefore a miniature Garden of Eden. "The World was my Garden" writes David Fairchild. "The World in Your Garden" writes W. H. Camp.

Someone needs to chronicle more completely the importance of horticulture to modern society. The fleur-de-lis appears in heraldry. The Chinese willow pattern involving peach tree, willows, and garden, is only one of many familiar horticultural designs on dinnerware and dinner service. Rugs, tapestries, wall paper, mural paintings, furniture, Corinthian columns, iron work, pottery, jewelry—all have some touch of horticulture. Bailey says: "Rob the race of the art suggestions that it has had from plants and you rob it of its architecture and its decorations".

In music we find the "Last Rose of Summer", MacDowell's "To a Wild Rose", Tschaikowsky's "Waltz of the Flowers". Most of such music is soft, warm, tender, or sweet. In poetry there are Wordsworth's daffodils in "I Wandered Lonely as a Cloud", Tennyson's "Flower in the Crannied Wall", the Mother Goose rhymes of childhood, Stevenson's "A Child's Garden of Verses", and the sentiments of James Whitcomb Riley. One of the most beautiful passages in literature is "consider the lilies of the field, how they toil not, neither do they spin; yet I say unto you that even Solomon in all his glory was not arrayed like one of these".

In triumph we give the laurel wreath, or in modern usage, "Orchids to you" — a combination of the highest phyllogenetic form and the ultimate in modernity! In sorrow, we give the funeral wreath and the floral tribute. In affection we offer flowers — "A rose by any other name, would be as sweet".

And if you will analyze, you will see that horticulture is associated mostly with the senses of sight, smell, taste, and touch — seldom with sound. It is entwined with the tender, with affection, with pleasure, with harmony, with refinement, with lovely form, pleasing flavors, colors, and aromas, and with beauty. It is touched by ease, luxury,

home and children. Conflict, bustle, clash of personalities, noise, and confusion, have no place in horticultural terminology.

It is because of some of these values, associated with healing, that medicine turns to horticulture. The nervous tensions of modern living are eased by the creative and muscular outlets of gardening. The cures that have been effected and the maladies that have been prevented are uncounted. "Horticultural therapy" is a branch that needs christening, study, and development.

On the social side, gardening is the safety valve of society. Better than standing armies and regimented recreation is the outlet of the garden. One may garden as little and as inexpensively as he likes, or as much and as extravagantly as he likes. With the drift to the cities, the country is found in the backyard garden and is carried indoors in house plants and window boxes. When grandmother can no longer tend her garden, she is found seated lovingly and shawl-covered in a rocking chair next the window in which are growing the plants that she loved best. Plants and gardens anchor society. A geranium growing in the yard signals a home of warmth, permanence, and hospitality.

Gardening means health, stability, and happiness. The 20 million Victory Gardens did more for America than produce food. The support which industry has given to the garden movement indicates the value it has found in gardening. The appointment of committees and commissions to promote better use of leisure time on the part of both rural and village people, is recognition of the trend. There must be more emphasis on living and less on making a living. This is the field in which horticulturists could well afford to spend more of their time, energy, and resources.

Conclusion

In conclusion, then, trying to sum up this all too hurried and all too incomplete discussion of some of the questions that concern us today, I doubt that I have contributed anything new but rather have probably only restated old truths. Yet I have tried to show that horticulture is a field involving plants — fruits, flowers, vegetables, ornamentals, nursery crops, and the like; that it represents a particular point of view; that it has its science side, its affairs side, and its artistic, esthetic, and social sides.

As scientists working in this field, horticulturists are biologists and must tie to biology, but as they are also horticulturists, they provide a bridge, a connecting link, the liaison. As L. H. Bailey has well stated, and I think that all I have said is condensed in this one sentence: "The horticulturist is the man who joins hands with the plant biologist on the one side and with the affairs of men on the other, and whose energies are expended in every way in which plants appeal to men". The horticulturist could do no better than to chart his course with this as his compass.

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